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期作對玉米農藝性狀雜種優勢表現之影響[1]

謝　光　照[2]

摘要：以三個馬齒型及三個硬粒型親本及其半互交的十五個 F_1 爲材料，分秋作、裡作及春作三期在農試所試驗田進行。目的在評估期作間產量之表現及雜種優勢之變化趨勢。試驗之結果摘要如下：玉米的開花期、吐絲期、單株葉面積、青割期整株乾物重、每穗子粒數、百粒重及成熟期子粒產量等在期作間具有極顯著差異存在。青割期整株乾物重的表現爲春作與裡作間沒有明顯差異，但均顯著大於秋作，子粒產量爲秋作與春作，春作與裡作間無顯著差異，但秋作明顯大於裡作。就組合而言，不論秋作、裡作或春作均以馬齒種 X 硬粒種組合具有較大的雜種優勢值。就期作而言，開花期及吐絲期，秋作及裡作比春作具有較大的雜種優勢值；而單株葉面積、青割期整株乾物重、每穗子粒數及子粒產量等性狀，以裡作不良環境下具有較大的雜種優勢值。此可能爲同型結合體的玉米自交系較異粒型結合 F_1 雜交種不能忍受逆境，致使生長較差，而突顯 F_1 優勢所致。

關鍵詞：玉米、期作、雜種優勢、雜種潛勢。

本省地處亞熱帶，適合玉米栽培，玉米在臺灣的生產季節，主要在春作或秋（裡）作，春作播種期一月上旬至三月中旬，秋作則在八月下旬至九月底，十月以後播種者爲裡作，期作間之氣象條件差異極大，通常春作由低溫，短日照逐漸轉爲高溫、多濕及較長日照之環境；而秋作則由高溫、長日照與多濕逐漸轉爲低溫、低濕及較短日照之環境；裡作則由中等溫度、中等日照長度及低濕度轉爲低溫、低濕度及較短日照，然後溫度及日照漸漸升高之氣象型態。玉米從種子發芽出土後，即受各種環境因子所影響，其中以溫度與光週期爲影響玉米植株生長及分化的兩項重要因子，筆者[6]研究結果顯示玉米生長分化性狀在期作間有明顯的差異存在。故在不同生長季節，常因氣象因子的變動玉米農藝性狀的表現呈現變異[1,3,4]，且基因型與環境間常有交感作用存在[13]，故某一基因型要表現出最佳的生長狀態，常須要特定的環境條件。

雜種優勢在玉米的利用上極爲重要且普遍，但環境因子如溫度、肥料及密度對雜種優勢的影響常被忽略，有些學者認爲在肥料供應充足及適當環境中雜種優勢才可發揮其最大潛力[8,11]；但有些報告則指出在不良環境下玉米會有較佳的雜種優勢值[9,20]。本省玉米子粒產量，呈現秋作最高，春作次之，裡作最低[3,4]，而其雜種優勢值的表現趨勢是否與子粒產量呈現相同的趨勢，有關之文獻尙缺。究竟在何種期作生長環境下，玉米雜種優勢才有最大的表現值，是一個值得探討的問題。本試驗目的即在探討期作對玉米青割及子粒產量等農藝性狀雜種優勢表現之影響。

材料與方法

本試驗所使用的自交系代號、譜系、來源及粒型如表 1 所列。三個馬齒型及三個硬粒型之半互交

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的15個 F_1 及6個親本，分秋作（1991年9月19日）、裡作（1991年11月7日、春作（1992年1月22日）等三期作播種於農試所試驗田。田間設計採逢機完全區集設計，三區集，三行區，行長4m，行株距70×20m，肥料施用量 N：P_2O_5：K_2O=180：90：60kg/ha，基肥以台肥39號複合肥料（N：P_2O_5：K_2O=12：18：12）每公頃施500kg，於播種前施入土內。其餘氮肥量以硫酸錏（N=21%）於齊膝期培土時施用。每穴兩粒採，出土2星期後間拔僅留一株，田間管理包括除草、中耕、培土及灌溉，均依照一般玉米栽培方法進行。各性狀之調查方法如下：

表1. 六個參試自交系之背景資料

Table 1. Backgrounds of the six inbred lines of maize evaluated.

Code	Inbred	Pedigree	Origin	Kernel type	Relative maturity
A	Hi25	(B14A×MV source)BC_4	Hawaii,USA	Dent	Early
B	Hi31	(B68×MV source)BC_5	Hawaii,USA	Dent	Late
C	Hi33	(Mo17×MV source)BC_5	Hawaii,USA	Dent	Early
D	Antigua-2D	Antigua	Caribbean	Flint	Late
E	Sw654	Suwan-1	Thailand	Flint	Intermediate
F	TA80-2598-44	(TA80−2598×Suwan−1)BC_3	TARI,Taiwan	Flint	Early

1. 開花期(days to tasseling)：係指由播種日起至小區中50%植株達雄穗始花所需之日數，以日表示。
2. 吐絲期(days to silking)：由播種日起至小區中50%植株雌穗開始吐絲所需之日數，以日表示。
3. 葉面積（leaf area per plant）：於吐絲後一星期每小區的中間行逢機調查10株，由頂端下數第八片葉的長度與寬度的乘積，再乘以0.75及9.39所獲的 cm^2 數值之平均值[16]。
4. 總乾物重（total plant dry weight）：於糊熟期，每小區取三株，在70°C下烘乾七天後，稱其乾重，以 g/3 plant 表示。
5. 每穗子粒數（kernel number per ear）：於子粒達生理成熟後，每小區採收中間行之五株之果穗之每穗子粒數。
6. 百粒重（100-kernel）：上述5穗脫粒後，逢機取100粒種子之重量，以 g 表示。
7. 子粒產量（grain yield）：於子粒達生理成熟後，每小區採收中間行之五株子粒產量，以 g/5 plant 爲單位。

試驗所得數據，先進行合併之變方分析及平均值顯著性測驗。同時估算各性狀在不同期作下之雜種優勢值〔heterosis, $H_1=(\bar{F}_1-\overline{MP})/\overline{MP}\times100$〕與雜種潛勢值〔heterobeltiosis, $H_2=(\bar{F}_1-HP)/HP\times100$〕[10]，$\bar{M}P$ 爲兩親本之平均值，HP 爲較高親本之值。

結　果

本試驗之期間從1991年9月至1992年6月底止，這段期間之旬平均氣溫、旬總日照時數及日夜溫差之變化，詳如圖1。從圖中可看出，秋作之氣溫由27°C漸降至16.5°C，其旬總日照時數約有750hr，而子粒充實期間累積日照時數約420hr；日夜溫差在子粒充實期間之變化由11.1～9.9°C，呈現較大之日夜溫差，累積值約812°C。裡作爲1991年11月7日播種，這段期間之旬平均氣溫由20°C下降至14.3°C，再漸漸增加至25.2°C，旬總日照時數之變化，由於陰雨天極多，故旬日照時數變化幅度極大，生育期間之總日照時數約900hr，特別是在子粒充實期間總日照時數之累積僅342hr左右，而其日夜溫差之累積爲712°C。春作爲1992年1月22日播種，生育期之旬平均氣溫由16.9°C漸漸增加至6月上旬之26°C，而其子粒充實期間之氣溫介於25.4～26°C，旬總日照時數之變化極大，整個生育期間之總日照時數約595 hr 左右，在子粒充實期間僅有173 hr 左右；子粒充實期間日夜溫差介於8.2～9.7°C之

間，其累積之數值爲440°C。由 Hunter *et al*[12]、Duncan et al[9]及盧[4]等栽培生理研究報告之佐證，綜合上述氣象因子之變化，可略知對玉米生長較有利之期作爲秋作，其次爲春作，最不利者爲裡作。

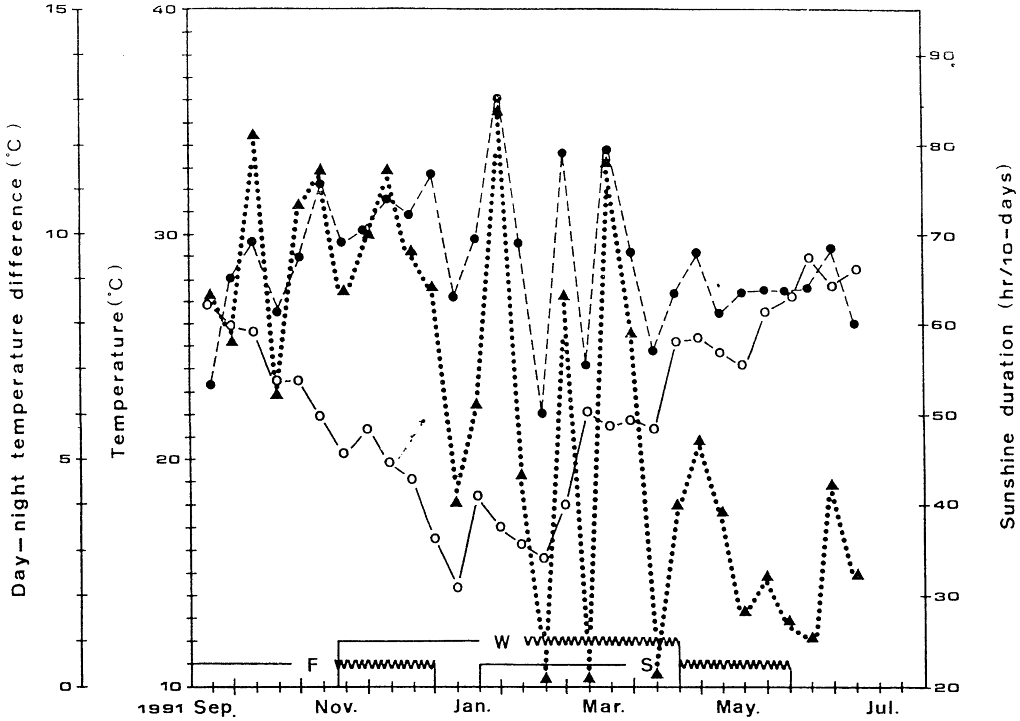

圖 1. 試驗期間（1991年 9 月至1992年 6 月）臺中霧峰地區之旬平均氣溫（○），旬總日照時數（▲）及旬日夜平均溫差（●）之變化。"F"，"S"及"W"表示秋作、春作及裡作；"〰"爲子粒充實期。

Fig. 1. Mean temperature per ten-days (○) ,sunshine duration of per ten-day (▲), and day-night temperature difference (●) at Wufeng (Taichung) area from September 1991 to June 1992. "F", "S" and "W" indicate fall, spring and winter, respectively. "〰" indicate grain filling stage.

所得數據合併之變方分析列於表 2，所調查的性狀在期作間均達顯著或極顯著之差異。基因型及基因型與期作之交感作用在所有性狀均呈現極顯著之差異。

表2. 六個自交系及其半全互交雜種在三個期作下農藝性狀之均方值

Table 2. Combined ANOVA for agronomic characteristics of six inbreds and their half-diallel hybrids of maize under three crop seasons.

Source of variation	Degree of freedom	Mean squares						
		Days to tasseling	Days to silking	Leaf ares per plant	Total plant dry weight	Kernel number per ear	100-kernel weight	Grain yield
Season	2	13,934.6**	13,577.2**	3,800**	226*	948**	218.9**	67.6**
Block/season	6	48.0**	54.6**	69*	12	5	29.9**	4.3
Genotype	20	141.2**	166.2**	843**	209**	809**	155.2**	233.9**
Season × genotype	40	12.7**	16.0**	47**	12**	39**	14.1**	8.9**
Error	120	2.2	3.2	28	6	20	3.8	3.1

*，** Significant at the 5% and 1% of probability levels, respectively.

期作間之平均值，列於表 3 ，由表中可看出由播種至開花期所需之日數，秋作爲59.1天，裡作爲86.1天，春作爲83.4天，吐絲期所需之日數也呈現相同的趨勢，秋作爲62.4天，裡作89.6天，春作爲85.5天。單株之葉面積以裡作（3904cm^2）最小，其次爲秋作（4646cm^2），最大者爲春作（5462cm^2），期作間呈現明顯的差異。青割整株乾物重（糊熟期），春作（610g/3 plant）與裡作（589g/3 plant）間沒有明顯差異，但均顯著大於秋作（497g/3 plant）。每穗子粒數之大小爲春作（393）＞秋作（356）＞裡作（316）。百粒重的變化爲秋作（24.4g）與裡作（23.9g）相近，而明顯大於春作（20.9g）。成熟期子粒產量之表現趨勢爲秋作（429g/5 plant）與春作（402g/5 plant），春作與裡作（364g/5 plant）間無顯著差異，但秋作明顯大於裡作。

表3. 期作間玉米各項農藝性狀之平均值

Table 3. Means for agronomic characteristics of maize under three crop seasons.

Crop season	Days to tasseling (day)	Days to silking (day)	Leaf area per plant (cm ^{2})	Total plant dry weight (g/3 plant)	Kernel number per ear (No.)	100-kernel weight (g)	Grain yield (g/5 plant)
Fall	59.1	62.4	4,646	497	356	24.4	429
Winter	86.1	89.6	3,904	589	316	23.9	364
Spring	83.4	85.5	5,462	610	393	20.9	402
LSD 0.05	3.2	3.4	639	97	31	1.2	45
LSD 0.01	5.2	5.7	1,061	161	51	2.0	75

三個期作平均之基因型之平均值列於表 4 ，由表中之值可知自交系比 F_1 雜交種較晚開花及吐絲外，其餘性狀均以 F_1 雜交種具有較大值。特別是整株乾物重、每穗子粒數及成熟期之子粒產量 F_1 雜交種均較自交系大一倍。自交系中，以 E 具有較大的單株葉面積、整株乾物重及子粒產量，而雜交種中 A×E、B×E、C×E、D×E、及E×F等均有較大的單株葉面積、整株乾物重及子粒產量。

將 F_1 雜交種按馬齒型×馬齒型（Dent×Dent）、馬齒型×硬粒型（Dent×Flint）及硬粒型×硬粒型（Flint×Flint）等畫分爲三類型，依不同類型組合在各期作下各項農藝性狀之雜種優勢值列於表 5 。雜種優勢值〔heterosis＝（F_1－MP）/MP×100〕之表現，開花期及吐絲期爲秋作與裡作無明顯差異，但均較春作來得大。單株葉面積雜種優勢值的大小呈現裡作＞秋作＞春作之趨勢。整株乾物重的表現爲裡作與春作相近，但均較秋作大。每穗子粒數之雜種優勢值，裡作明顯的大於秋作與春作，而秋作與春作間之雜種優勢值相近。百粒重之表現趨勢爲秋作≒春作＞裡作。成熟期子粒產量之雜種優勢值則呈現裡作＞春作≒秋作之現象。而各項農藝性狀在不同期作下，除百粒重在春作外，其餘性狀之表現則以馬齒型×硬粒型之組合具有較大之雜種優勢值。

由雜種優勢值（H_1）及雜種潛勢值（H_2）正負值之變化，可知雜種優勢值的表現是以何種基因之作用型式爲主。三個期作各項農藝性狀之雜種優勢值（H_1）及雜種潛勢值（H_2）列於表 6 。由表中之數值變化，可看出開花期、吐絲期、單株葉面積、整株乾物重、每穗子粒數、百粒重及子粒產量等之雜種優勢值的表現，在三期作之環境下均以超顯性基因（overdominance）作用爲主。

表4. 玉米不同基因型各項農藝性狀之平均值

Table 4. Means for agronomic characteristics of maize genotypes.

Genotype	Days to tasseling (day)	Days to silking (day)	Leaf area per plant (cm^2)	Total plant dry weight (g/3 plant)	Kernel number per ear (No.)	100-kernel weight (g)	Grain yield (g/5 plant)
A	78.4	82.2	3,091	319	171	20.0	126
B	85.1	87.9	3,343	337	180	20.2	137
C	75.2	79.1	3,549	343	261	18.5	193
D	83.0	87.4	4,221	464	282	15.1	224
E	81.6	84.1	4,749	521	333	22.2	365
F	80.1	84.2	2,347	315	214	16.8	152
Mean	80.6	84.2	3,550	383	240	18.8	200
AB	79.1	83.0	3,802	353	212	22.7	198
AC	71.6	74.4	3,936	542	353	22.3	358
AD	72.7	75.5	5,264	665	384	23.7	449
AE	72.6	74.3	5,903	714	422	30.9	633
AF	72.0	74.3	4,890	549	410	23.0	453
BC	75.7	78.3	5,281	644	407	24.3	461
BD	76.0	79.0	5,487	705	415	25.6	510
BE	77.5	79.1	5,869	793	410	29.6	573
BF	75.8	78.0	4,765	636	428	25.1	518
CD	72.0	74.9	4,842	627	448	20.1	446
CE	73.7	75.9	5,940	655	389	30.7	552
CF	70.0	73.2	4,888	603	435	20.7	438
DE	76.0	79.1	5,458	737	465	23.5	529
DF	76.3	80.4	4,526	703	441	22.7	503
EF	75.8	78.4	4,938	647	399	26.9	551
Mean	74.4	77.2	5,053	638	401	24.8	478
LSD 0.05	1.4	1.7	497	76	42	1.8	52
LSD 0.01	1.8	2.2	657	100	56	2.4	69

表5. 不同粒型組合在不同期作下各種農藝性狀之平均雜種優勢值 (H_1,%) [z]

Table 5. Heterosis (H_1,%)[z] for agronomic characteristics of different kernel type combinations under three crop seasons in maize.

Crop season	Kernel type	Days to tasseling	Days to silking	Leaf area per plant	Total plant dry weight	Kernel number per ear	100-kernel weight	Grain yield
Fall	Dent×Dent	− 7.28	− 6.65	50.20	26.52	50.77	22.33	88.40
	Dent×Flint	−10.67	−12.44	58.40	52.73	55.98	39.39	124.00
	Flint×Flint	− 7.93	− 9.09	35.99	46.77	48.58	39.43	101.95
	Mean	− 9.40	−10.60	52.30	46.30	53.40	36.00	112.00
Winter	Dent×Dent	− 6.79	− 6.78	60.51	79.86	122.22	8.45	290.40
	Dent×Flint	−11.12	−12.63	73.67	95.20	150.52	31.85	399.21
	Flint×Flint	− 8.47	− 8.40	42.45	73.20	97.68	28.70	215.76
	Mean	− 9.70	−10.60	64.80	87.70	134.30	26.50	347.00
Spring	Dent×Dent	− 3.85	− 2.93	35.73	61.19	29.38	26.90	92.36
	Dent×Flint	− 4.40	− 4.59	43.95	89.96	59.79	35.01	131.66
	Flint×Flint	− 4.10	− 3.31	34.61	70.64	44.44	38.19	127.09
	Mean	− 4.20	− 4.00	40.40	80.30	50.60	33.90	122.00
	LSD 0.05	4.10	4.45	26.91	67.85	59.88	20.09	137.08

[z] $H_1 = \frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$

表6. 三個期作各項農藝性狀之雜種優勢 (H_1,%)^z 及雜種潛勢 (H_2,%)^{y}估值
Table 6. Heterosis (H_1,%)^z and Heterobeltiosis (H_2,%)^y for agronomic characteristics under three crop seasons in maize.

	Crop season	Days to tasseling	Days to silking	Leaf area per plant	Total plant dry weight	Kernel number per ear	100-kernel weight	Grain yield
H_1	Fall	− 9.4	−10.6	52.3	46.3	53.4	36.0	112.0
	Winter	− 9.7	−10.6	64.8	87.7	134.3	26.5	347.0
	Spring	− 4.2	− 4.0	40.4	80.3	50.6	33.9	122.0
H_2	Fall	−11.1	−12.9	20.0	22.5	34.3	23.5	73.5
	Winter	−12.6	−13.0	40.5	55.1	94.6	13.4	211.6
	Spring	− 5.8	− 5.7	26.9	66.0	28.1	21.6	74.4

^{z} $H_1=\frac{\bar{F}_1-\overline{MP}}{\overline{MP}}\times 100$

^{y} $H_2=\frac{\bar{F}_1-\overline{HP}}{\overline{HP}}\times 100$

討 論

本省春、秋及裡作之氣象條件差異極大，筆者[6]在春作及秋（裡）作環境下，曾探討期作間生長分化的表現情形，結果顯示，玉米生長分化性狀在春作正值低溫，秋裡作則正值高溫，致生長分化在期作間有極大的差異存在，春作顯然比秋裡作在出土至雄穗分化日數、雄穗分化始期葉片出現數目、生殖生長期葉片出現速率、單株葉面積等較大；而營養生長期葉片出現速率、雄穗與雌穗分化間隔日數及葉片分化速率均較小。作物的產量是一個相當複雜的性狀，受遺傳與環境因子的控制。氣候環境因子中對作物生長影響最直接的爲溫度與日照。Hunter *et al*[12]指出，在較長日照下玉米植株平均每日乾物質生產量較多，主要是由於有較大的葉面積，能增加光合產物；而在較低溫下，子粒產量則較大，主要是子粒充實期增長及開花後有較高比例的乾物質累積在子粒。本試驗之結果顯示，單株葉面積爲春作最高，其次秋作，裡作最小，而青割（糊熟期）總乾物重爲春作與裡作，裡作與秋作無明顯差異，但春作大於秋作；而成熟期子粒產量的表現則爲秋作大於裡作，而春作與裡作間雖呈現春作大於裡作之趨勢，但無明顯差異存在。可能秋作玉米營養生長期溫度日照均高，生長較快，營養生長期短，生殖生長期氣溫低、日夜溫差大，因此不僅有利於葉片之發育，且有利於功能之維持，且由於子粒充實期增長及開花後有較高比例的乾物質累積於子粒，致使子粒之產量呈現秋作最高；裡作玉米營養生長期適逢低溫及低日照量，減緩玉米生長速率，致使葉片發育不良，呈現單株葉面積及葉面積持續期均低，至生殖生長期雖溫度略有升高，卻使得整個生長時期增長，有較多之光合產物累積於營養器官，但子粒充實期間由於日照時數減少、日夜溫差小及平均氣溫稍高等氣象因子，不利於乾物質累積至子粒，致其子粒產量最低；春作玉米營養生長期之溫度低，日照強度不高，而生殖生長期有明顯之升高，在此種環境下葉部發育良好，故使開花期之單株葉面積大，但因植株老化快速而使葉面積持續期降低，供源強度亦因而降低，加上生殖生長期高溫而縮短子粒充實期，不利於乾物質分配至子粒部位，致子粒產量之表現介於秋作與裡作之間[4]。故造成期作間玉米青割（糊熟期）總乾物重之表現爲春作＞裡作＞秋作之現象；而子粒產量則呈現秋作＞春作＞裡作之趨勢。

雜種優勢的表現主要來至非累加性之遺傳因子，而非累加性基因之表現極易受環境所影響[19]，

本試驗之結果顯示玉米的開花期及吐絲期之雜種優勢之表現趨勢呈現秋作與裡作明顯地大於春作，可能因環境因子對玉米開花期及吐絲期之影響，呈現溫度效應遠大於日長效應之結果[19]，且低溫對開花期及吐絲期均有延遲現象，而自交系所受到的影響遠大於 F_1 雜交種，秋作及裡作玉米的開花期及吐絲期正值較低溫，致使在期作間雜種優勢值呈現秋作及裡作較春作大之現象，與謝等[5]之結果相符。而單株葉面積的雜種優勢值呈現裡作＞秋作＞春作之趨勢；青割整株乾物重的雜種優勢值則爲裡作≒春作＞秋作；成熟期子粒產量雜種優勢之表現趨勢爲裡作＞春作≒秋作，可能因玉米自交系爲同型結合體，一般同型結合體比異型結合體較不能忍受逆境的環境[7]，致使玉米自交系在裡作之生長較春作及秋作來得差，而雜交種對逆境（低溫）的忍受力較高[18]，因此使得玉米的單株葉面積、青割乾物重、每穗子粒數及子粒產量之雜種優勢值的表現，在不良環境下會較佳，故呈現裡作較大之趨勢[7]；而於秋作之較優良環境下呈現較小之雜種優勢值[14]。

種源間之遺傳歧異性是造成雜種優勢表現之主要原因[17]。遺傳歧異性不僅存在於不同粒型種源間或不同地區來源之種源間，亦可能存在於同粒型或同地區來源之種源內，因此在同粒型品系間，亦有可能在某些雜交組合中表現優良的雜種優勢[15]。Prasad and Singh[17]認爲適中的遺傳歧異性可導致最高雜種優勢之表現。本試驗之結果顯示馬齒型×硬粒型之組合的農藝性狀，不論在秋作、裡作或春作環境下，均具有較大之雜種優勢值；而雜種優勢之表現主要以非累加性成份中之超顯性基因爲主。由上述之結果可知馬齒型×硬粒型之組合爲臺灣飼料玉米育種上一優良之雜種優勢之模式[2]。

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The Effects of Crop Seasons on the Heterosis of Agronomic Characteristics in Maize[1]

Guang-Jauh Shieh[2]

Summary

A total of six maize inbreds (three dents and three flints) and their half-diallel hybrids were used as materials to collect the basic information for breeding high yielding maize in Taiwan. The experiment was conducted at the research farm of Taiwan Agricultural Research Institute nearly Wufeng, Taichung, under fall, winter and spring crop seasons, The results were summarized as follows. A highly significant difference due to the three crop environmental conditions was observed for all characteristics investigated. The total plant dry weight produced under spring season was heavier than that produced under fall season, and a nonsignificant difference was found between spring and winter crop seasons. However, fall crop season produced more grain yield than winter season. Viewing the heterosis values of various hybrids under the three crop seasons, a tendency of relatively high heterosis values for all of dent X flint combinations under three crop seasons was observed. On the other hand, under fall and winter crop condition, a relatively high heterosis value was observed for the day to tasseling and day to silking, but under winter crop condition, a relatively high heterosis valus was observed for the leaf area per plant, total plant dry weight, kernel number per ear, and grain yields. This might be inferred and emphasized from the fact that homozygous inbreds were less stress resistant to winter condition than heterozygous hybrids, and thus, hybrids had relatively high heterosis values under winter.

Key words : Maize, Crop season, Heterosis, Heterobeltiosis.

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青割玉米單雜交種臺農2號之育成[1]

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摘要：臺農2號爲單雜交種，屬於青割玉米，其母本及父本自交系分別爲 SW558及 TA 3651-377。母本係由泰國 Kasetsart 大學引進之抗露菌病種源 Suwan-1 DMR 經自交分離育成，屬硬粒種，莖葉茂盛，抗普通型銹病、煤紋病及露菌病；父本 TA3651-377係由美國夏威夷大學引進之自交系 Hi31經純化選出者，屬馬齒種，一般組合力高，對露菌病及煤紋病有抗性，且具有強稈抗倒伏之特性。

臺農2號青割鮮草產量可達50公噸／公頃，綜合兩年區域試驗之總平均產量較對照種臺南白高25.7%，較臺農351號增加14%，較臺農1號高出11.6%。本品種之莖稈粗壯，株型高大，穗位與臺農351號及臺農1號高度相近，抗倒伏性強，開花期及吐絲期之間隔爲2～3天左右，果穗爲1-2穗，鮮草產量高，自糊熟期至生理成熟期皆可收割。開花期與成熟期隨溫度高低之變化甚大，播種至吐絲期，春作約70天，秋作約65天。生育日數，春作三月初播種至子粒生理成熟期約106天，秋作八月底播種者約110天，屬中晚熟品種，適合本省耕作制度。本品種對普通型銹病及露菌病具有高度抗性，煤紋病爲中抗，不抗矮化嵌紋毒素病。

臺農2號植株之莖色及葉鞘色爲綠色，葉片深綠色，葉片數15～16片，花葯黃色，穎色及花絲淡紅色，果穗苞葉緊密，每株穗數1～2穗，籽粒行數14～16行，籽粒呈馬齒型橘黃色。

關鍵詞：青割玉米、馬齒種、硬粒種。

以青割玉米作成的青貯料（silage）或青飼料（forage），是一種嗜口性（palatability）佳且營養價值頗高的芻料，故有芻料之王（king of forage）之稱，其用來飼餵乳牛，更可提高泌乳量及乳脂率[11]。目前政府正大力推行稻田轉作計畫，玉米是主要推薦作物之一，青割玉米自播種至收穫可完全機械化操作，在降低生產成本及解決農村勞力不足問題上，均較其他轉作作物有利。因此，推廣青割玉米不但可加速稻田轉作計畫之推展，同時更可促進本省乳牛、肉牛事業之蓬勃發展。

臺灣牧草生產，夏季過剩而冬季不足，青割玉米適合秋裡作栽培，適可因應急需。目前部份農戶以臺南白玉米、飼料玉米臺農一號或自國外進口之 XL678作爲生產青割玉米之用。青割玉米的生產目標以高乾物質產量、高營養價值及高消化性[9]爲主，此與飼料玉米[1,3]略有不同，飼料玉米僅利用果穗部份，而青割玉米則爲整株利用。本所利用國內外玉米種源，依玉米育種程序，期能選育抗倒伏、耐密植、產量高且品質優之青割玉米，以因應國人酪農及養牛事業迫切之需要。本所有鑑於此，乃積極從事青割玉米品種選育工作，近期育成符合上述要求之青割玉米品種臺農2號，經申請命名登記並審查通過。

材料與方法

一、組合力檢定

1. 臺灣省農業試驗所　研究報告第 1746 號。
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自 Suwan-1 DMR 分離所獲之202個自交系與臺南11號進行頂交與比較試驗，由其中獲選之80個優良系統，再與 8 個檢定親進行測交與比較試驗。田間比較試驗，採順序排列，2重複，單行區，行長5 m，行株距75×25cm。

二、新品系比較試驗

較優之 Suwan-1 DMR 分離系17個與 B77及 TA 3651-377進行測交與比較試驗，田間比較試驗採逢機完全區集設計、4 種複、3 行區、行長 5m、行株距70×25cm。

三、區域試驗

(一)77年春作：H-7等8個品系以臺南白及臺農351號爲對照種，在彰化、雲林、嘉義、屏東、臺東、花蓮及新竹等7個地區進行。田間採逢機完全區集設計，4 重複、行長6 m、6 行區、行株距70×20cm。

(二)77年秋作：H-7等6個品系以臺南白及臺農351號爲對照種，在彰化、雲林、嘉義、屏東、臺東、花蓮及新竹等7個地區進行。田間設計同前。

(三)78年春作：參試品系同77等秋作，對照種則增加臺農1號，在苗栗、雲林、嘉義、屏東、臺東、花蓮等六地點舉行。田間設計同前。

(四)78年秋作：77年秋作青割玉米新品系區域試驗，農試所提供表現較佳的 H-7及 E-7參試，而臺南場更換新品系，以 Si-7及Si-16兩新品系參加，對照種爲臺農351號及臺農1號，田間設計同前。

四、穩定性分析

由區域試驗之數據，選開花期、吐絲期、株高、穗位高、鮮草產量等農藝性狀，依期作別進行穩定性分析[8]。

五、氮肥及密度試驗

於78年秋作至79年春作，在彰化、苗栗、花蓮及嘉義四個地點進行，採裂區設計，N 肥主區，密度副區，品系副副區（Si-4及 H-7），4 行小區，密度分70×15、70×20、70×25cm，磷肥（P_2O_5）爲90kg/ha，鉀肥（K_2O）爲60kg/ha，氮肥分爲150、200、250、300kg/ha，重複四次。分春、秋、裡三期作進行。

六、病害檢定

病害檢定品系有 H7、SW558、TA3651-377及對照品種等。病害檢定項目有毒素病、莖腐病、銹病、煤紋病、葉斑病、露菌病。

(一)玉米普通型及南方型銹病：

1. 幼苗檢定（檢定直式抗病性）：種子發芽後置於生長箱中培育，至4～6片葉完全展開時，以噴霧器接種病原，經6～10天記錄發病程度，依照孢子堆數目與標準比對表比對，區分爲極抗（0～5%）、抗（6～10%）、中抗（11～30%）；感（31～60%）及極感（61～100%）等5級。
2. 成株檢定（檢定橫式抗病性）：在東部建立檢定圃，利用存在於田間之病原天然接種。於每年2～3月間播種，至開花後調查發病程度，與標準孢子堆數目比對表比對，區分受檢材料爲極抗、抗、中抗、感、極感等5級。

(二)玉米煤紋病：

1. 幼苗檢定（檢定直式抗病性）：種子發芽後置於生長箱中培育，至植株長至6～7片葉時，以噴霧器接種病原，並以透明塑膠布覆蓋保持濕度，溫度保持在24°C±1°C，光照時間12小時，經過24小時後掀去塑膠布。接種後15天，調查發病結果，依發病程度區分受檢材料爲極抗（0～5%）、抗（6～10%）、中抗（11～30%）、感（31～60%）、極感（61～100%）

等5級。

2. 成株檢定（檢定橫式抗病性）：本病春作較易發生，因此選擇易於發病之地區設立檢定圃。受檢材料於每年2～3月播種，亦加入感病品種以提高接種源。植株開花後調查發病情形，依照幼苗檢定標準，按發病程度同樣區分為5級。

㈢葉斑病：

1. 幼苗檢定：同煤紋病。
2. 成株檢定：利用病圃種植，經田間自然發病進行調查。由於葉斑病全年均會發生，因此春秋兩季均可檢定。檢定時亦應加入感病品種為接種原，開花後記錄病徵，按發病程度區分為極抗（0～5%）、抗（6～10%）、中抗（11～30%）、感（31～60%）、極感（61～100%）等5級。

㈣玉米露菌病：先種植感病之甘蔗以建立病圃，於每年3月初或10月底，在病圃內播種玉米，利用罹病甘蔗所產生之孢子自然接種，至病徵出現後進行調查發病率，並區分供試材料為極抗（0～5%）、抗（6～20%）、中抗（21～50%）、感（51～80%）、極感（81～100%）等5級。

㈤玉米毒素病：春秋兩季，晝溫20～30°C時，供試玉米品系於3～4葉齡期，接種玉米矮化嵌紋病毒 B 型系統（MDMV-B），置溫室中，7 天與15天分別調查病徵，判定各株之病害係數（disease coefficient）。完全無病徵者，係數為 0；第7天調查出現黃斑嵌紋或局部病斑，但第15天調查時新生葉並未出現系統性病徵，係數為 2，第7天調查時無病徵，第15天調查時才出現系統性病徵，係數為 3；急速型系統性病徵者，兩次調查都有明顯病徵，但病勢發展較快，係數為 4。根據每個品系各株的病害係數，算出該品系的病害指數（disease index；D.I.）。$D.I.=100x(4 x N_1+3 x N_2+2 x N_3+0 x N_4)/(N_1+N_2+N_3+N_4) x4$，式中 N_1、N_2、N_3、N_4及4、3、2、0 分別為該係數項下之植株數與病害係數。供試品系依據其 D.I. 值區分為極抗（0～5%）、抗（6～20%）、中抗（21～50%）、感（51～80%）、極感（81～100%）等5級。

㈥莖腐病：於隔離檢定圃播種玉米，俟植株長至40公分高時，將病原接種於離地面第二節莖稈上，接種一星期，調查發病率，依發病率，區分供試品系為極抗（0～5%）、抗（6～20%）、中抗（21～50%）、感（51～80%）、極感（81～100%）等5級。

七、蟲害檢定

蟲害則檢定亞洲玉米螟之危害等級，分輪生期及開花期兩次檢定。其詳細方法如下：

㈠玉米螟：

1. 輪生期玉米抗螟性檢定：室內以人工飼料大量繁殖玉米螟並收集卵塊，在玉米生長至45～50㎝後，將卵塊接種於心葉內，連續接種3～4次，每次每株接種卵塊2個每次接種間隔2天。於第一次接種21天後，檢查植株之抗蟲性。並將植株之抗蟲性分為5等級。

   1 級（極抗）：葉面上不見食痕，或少許如針孔狀食痕或數葉片上有如子彈射穿食痕。

   2 級（抗）：數片葉面具有子彈射穿食痕或少許長型食痕。

   3 級（中抗）：半數以下葉片有長型食痕，食痕長度不超過2.5公分。

   4 級（感）：半數以上，三分之二以下葉片具長型食痕，其長度超過2.5公分。

   5 級（極感）：三分之二以上葉片具長型食痕，其長度超過2.5公分。

2. 開花期玉米抗螟性檢定：在玉米開花期，將卵塊接種於雌穗上下葉之葉脈上，連續接種3～4次，每次每株接種2個卵塊。每次間隔2天。接種50～60天後，用刀將玉米莖縱面剖開，測量莖內玉米螟幼蟲食痕長度，其長以公分（㎝）表示之。供試玉米抗螟性分下列等級：

1 級（極抗）：玉米莖無受害狀，或食痕長度在 5 公分以下。

2 級（抗）：食痕長度在 6 ～10公分間。

3 級（中抗）：食痕長度在11～30公分間。

4 級（感）：食痕長度在31～40公分間。

5 級（極感）：食痕長度在41公分以上。

八、臺農育 H7號與 XL678產量比較試驗

於80年秋至81年秋作，在農試所進行，採逢機完全區集設計，4 重複，行長 5 m，行株距70×20 cm，6 行區，小區面積21m²，於黃熟期進行青割取樣工作。

九、品質分析

78年秋作至79年春作，本所提供種子（H7及TNG1），供中興大學研究生進行品質分析，飼料成份分析項目包括水分含量、灰分含量、粗蛋白質含量、粗脂肪含量、粗纖維含量及無氮抽出物含量等。

將青割玉米區分爲葉片（含葉鞘）、苞葉、莖稈、子粒及全株等，烘乾後磨粉，以便進行飼料成分分析：

㈠水分含量（moisture content）

稱取樣品 2 ～ 5 g，放入105°C烘乾箱乾燥 3 ～ 5 小時，取出放乾燥器內恢復至室溫，儘速秤重完畢，再度乾燥後秤重，直至恆重，此時失重百分率即爲樣品水分含量。

㈡灰分含量（ash content）

將磁坩堝洗淨置於105°C烘乾箱烘乾一小時，取出放入乾燥器恢復至室溫後秤重，再加入樣品 2 ～ 5 g，移入灰化爐逐漸加溫至600°C燃燒 4 ～ 6 小時，關閉電源待溫度降至150～200°C時，將磁坩堝移入乾燥器恢復至室溫後秤重，此殘留部分即爲灰分。

㈢粗蛋白質含量（crude protein content）

秤取0.2g樣品置於分解瓶中，加入 4ml H_2SO_4及0.2g 催化劑（K_2SO_4：$CuSO_4$，$5H_2O$：Se＝50：10：1，W/W），加熱分解至澄清，冷卻後，加蒸餾水稀釋至50ml。取 5 ml 稀釋液至 Kjeldehl 蒸餾瓶，加入 5 ml 10N NaOH 進行蒸餾，以 4 %硼酸加指示劑吸收蒸餾出之液體，再用0.01N HCl 滴定並記錄滴定數，換算爲全氮含量，再乘以6.25即爲粗蛋白。

㈣粗脂肪含量（crude fat content）

脂肪接受瓶經洗淨後，在105°C烘乾 1 小時，放入乾燥器恢復至室溫秤重，秤取樣品 2 ～ 5 g，包於濾紙放入濾筒並放進 Soxhlet 乙醚抽出器內，加入適量乙醚（石油醚）將樣品浸漬迴流入脂肪接受瓶，連續淬取16小時，將脂肪完全抽出後，置於適當位置待乙醚揮發後，放入105°C烘乾箱乾燥 3 ～ 5 小時，再放入乾燥器恢復至室溫，取出秤重即爲粗脂肪重。

㈤粗纖維含量（crude fiber content）

將乙醚抽出之樣品烘乾放入高脚燒杯，加入200ml 1.25%硫酸液及幾滴 Octyl alcohol，在電爐上加熱煮沸30分鐘後，再以熱水過濾，將濾紙上殘留物以200ml 1.25% NaOH 洗入高脚燒杯，煮30分鐘後，趁熱過濾，再以熱水洗淨，並將濾紙上殘留物洗入坩堝中，再將留有粗纖維之坩堝，放入105°C烘乾箱乾燥3～4小時，取出放入乾燥器恢復至室溫稱重，再移入灰化爐灰化後，取出放入乾燥器恢復至室溫稱重，所失去重量即爲粗纖維。

㈥無氮抽出物（nitrogen-free extract content；NFE%）

NFE%＝100%－水分%－灰分%－粗蛋白%－粗脂肪%－粗纖維%

十、主要農藝性狀之調查方法

㈠開花期：由播種至小區中50%植株達雄穗始花所需日數。

(二)吐絲期：由播種至小區中50%植株達雌穗開始吐絲所需之日數。
(三)株高：小區逢機取 5 株由地面至雄穗頸節位的平均高度，以 cm 表示。
(四)穗位高：小區逢機取 5 株由地面至最上雌穗基部平均高度，以 cm 表示。
(五)倒伏率：傾斜45°爲基準，註明所佔小區株數之百分比。
(六)青割收穫期：以手指擠壓籽粒不再有乳狀汁液流出之時期。
(七)鮮草產量：小區青割整株之總鮮重，或換算成公頃產量，以 kg/小區面積或kg/ha 表示。
(八)整株乾物率：鮮草在乾燥機中，以70°C烘七天後之乾物率。
(九)果穗百分比：果穗乾物質佔全株乾物質之百分比。
(十)總營養消化率（TDN%）：$\frac{(\text{果穗乾重} \times 0.85) + (\text{莖葉、苞葉乾重} \times 0.582)}{\text{整株乾物重}} \times 100$。

結果與討論

一、親本來源及特性：

臺農育 H-7 號爲單交種，由自交系 SW558及 TA3651-377雜交而成。母本 SW558係自泰國 Kasetsart大學引進抗露菌病種源 Suwan-1 DMR 經自交分離至 S_5所育成之自交系，屬硬粒種（flint），莖葉茂盛，抗普通型銹病、煤紋病及露菌病，具高產潛力；父本 TA3651-377係由美國夏威夷大學引進之自交系 Hi31經純化選出者，屬馬齒種（dent），一般組合力高，對露菌病及煤紋病有抗性，且具有強桿抗倒伏之特性。父母本雜交組合符合硬粒種 x 馬齒種之雜種優勢模式[6,7]。

二、各級試驗及檢定結果

(一)組合力檢定：

Suwan-1 DMR 族群經自交分離育成202個 S_5系統（以下稱 SW 自交系），與臺南11號進行頂交比較試驗，由其中選出組合力與抗病性較佳之系統80個。於73年秋，利用 TA80-1410-1（臺農351號父本改良系之一）、TA80-2598（臺農351號母本）、Hi 25（美國 B14A 改良系）、Oh545（美國 Oh 54改良系）、B77（美國 Pioneer2-ear comp 分離系統）、Narino 330（古巴硬粒種）、Fla-2AT-113及 TA3651-377（Hi31）等 8 個自交系檢定親完成測交種子生產。於74年秋作進行測交種產量比較試驗，結果發現 SW 分離之自交系與 TA80-1410-1、B77及 TA3651-377等三個溫帶型玉米種源之組合，產量均高；而其與熱帶型硬粒種如 TA80-2598，Narino 330及 Fla-2AT-113或溫帶型種源如 Hi25及 Oh545等之組合，平均產量則較低。由試驗中選出17個組合力較佳之自交系，SW558即爲其中較優異的一個，其植株及青割產量性狀均相當突出。

(二)新品系比較試驗

75年春作將17個最優異之 SW 自交系分別與 B77及 TA3651-377雜交，其中與 B77及 TA3651-377之雜交組合分別以 E 及 H 爲代號，75年秋在相鄰試區進行試驗，並以臺農351號爲對照種，田間採逢機完全區集設計，3 行區，行長 5m，行株距70×25cm，4 重複。每小區之最中間一行調查青割產量。試驗結果，小區鮮草產量以 H-7、H-41、E-7及 E-8等四個新品系較高，同時其乾物重也較高，故獲選參加新品系區域試驗（表 1 及表 2）。

表1. 新品系比較試驗 H 組之試驗成績

Table 1. Agronomic characters of group H in new combination yield trials.

Entry	Days to tasseling (day)	Plant height (cm)	Ear height (cm)	Whole-plant dry matter content (%)	Ear percentage (%)	Fresh weight (kg/6.5m²)
H-6 (SW556×TA3651-377)	60.2	265	102	29.1	53.0	28.9
H-7 (SW558×TA3651-377)	59.0	257	110	29.5	55.1	33.2
H-8 (SW560×TA3651-377)	59.2	252	105	31.2	56.9	32.3
H-9 (SW562×TA3651-377)	59.0	263	118	31.3	57.1	29.9
H-12(SW567×TA3651-377)	60.2	253	102	28.6	53.8	29.8
H-13(SW589×TA3651-377)	58.2	261	107	28.1	51.8	28.8
H-26(SW598×TA3651-377)	61.5	271	115	29.3	56.2	31.7
H-34(SW621×TA3651-377)	62.0	268	116	30.5	54.0	31.1
H-36(SW626×TA3651-377)	59.2	265	102	28.9	55.3	31.6
H-41(SW646×TA3651-377)	61.5	262	107	27.5	52.1	33.0
H-43(SW650×TA3651-377)	61.0	256	102	30.8	58.8	30.6
H-44(SW654×TA3651-377)	60.7	261	110	28.7	54.1	32.3
H-45(SW655×TA3651-377)	60.5	252	100	30.5	61.5	26.4
H-47(SW658×TA3651-377)	59.7	256	106	29.7	52.7	31.4
H-52(SW672×TA3651-377)	62.2	266	113	31.6	56.4	30.2
H-68(SW711×TA3651-377)	61.2	258	108	30.8	53.6	29.6
H-77(SW734×TA3651-377)	61.5	258	108	30.8	56.0	26.7
TNG-351	61.0	260	113	28.3	52.2	28.7
$LSD_{0.05}$	2.0	18	10	4.5	4.9	3.6

表2. 新品系比較試驗 E 組之試驗成績

Table 2. Agronomic characters of group E in new combination yield trials.

Entry	Days to tasseling (day)	Plant height (cm)	Ear height (cm)	Whole-plant dry matter content (%)	Ear percentage (%)	Fresh weight (kg/6.5m²)
E-6 (SW556×B77)	61	275	113	30.3	55.9	30.0
E-7 (SW558×B77)	60	275	106	30.6	57.7	32.7
E-8 (SW560×B77)	60	281	115	28.2	54.9	33.9
E-9 (SW562×B77)	61	281	123	29.6	54.0	31.7
E-12 (SW567×B77)	63	270	104	32.2	58.6	27.8
E-13 (SW589×B77)	60	275	106	33.5	55.6	27.9
E-26 (SW598×B77)	62	285	113	28.8	50.7	30.5
E-34 (SW621×B77)	62	286	106	29.3	54.5	32.0
E-36 (SW626×B77)	61	271	104	33.3	55.0	25.7
E-41 (SW646×B77)	60	271	110	30.5	57.6	30.0
E-43 (SW650×B77)	59	258	108	35.6	56.1	26.7
E-44 (SW654×B77)	60	281	116	33.2	54.3	28.2
E-45 (SW655×B77)	60	286	111	31.3	55.2	29.4
E-47 (SW658×B77)	60	286	115	30.3	58.6	31.2
E-52 (SW672×B77)	60	285	113	33.3	56.8	27.8
E-68 (SW711×B77)	59	279	105	31.3	56.4	26.5
E-77 (SW734×B77)	59	270	101	33.5	53.4	27.4
TNG-351	61	259	115	28.8	50.5	29.2
$LSD_{0.05}$	3	17	11	4.5	4.6	5.8

㈢區域試驗

1. 77年春作

綜合77年春作全省7個地點之平均（表3），H-7之公頃鮮草產量達50,256kg，較臺農351號高出14.6%；H-41公頃鮮草重爲51,938kg，較對照種臺農351號高出18.4%，然其株型及果穗性狀較差，且易感染紋枯病，故予以淘汰。區域試驗方面，在二林試區 H-7、H41及 NKSI-2之公頃鮮草產量均較臺農351號及臺南白爲優，達到顯著差異；崙背試區 H-7達67,381kg，較臺農351號高出26.1%；民雄試區 H-7爲60,453kg，較對照種臺農351號之44,191kg 高出36.8%；豐里及竹東地區 H-7與對照種無明顯差異；屏東及瑞穗地區，H-7之鮮草產量均較高，唯差異未達顯著。

表3. 77年春作區域試驗各項農藝性狀之平均值

Table 3. Location mean of agronomic characters in regional yield trial of spring 1988.

Entry	Days to tasseling (day)	Days to silking (day)	Plant height (cm)	Ear height (cm)	Fresh weight (kg/ha)	Rust (1-5)	*H. turcicum* (1-5)	*H. maydis* (1-5)	Lodging (%)
H-7	71.5	75.7	243	126	50,256	1.5	1	1.2	14.9
E-7	71.4	74.0	242	122	47,406	1.5	1	1.3	15.0
E-8	70.4	74.0	233	121	46,584	1.5	1	1.5	6.5
H-41	71.2	74.9	239	124	51,938	1.5	1	1.4	10.4
NKSI-1	69.8	73.7	231	116	45,195	1.5	1	1.4	8.9
NKSI-2	72.0	76.3	233	120	46,424	1.6	1	1.2	12.5
NKSI-3	70.9	74.7	228	99	45,134	1.5	1	1.0	16.0
NKSI-4	71.2	74.8	231	116	44,892	1.5	1	1.2	15.5
TN white	69.6	73.2	239	129	43,028	1.7	1	1.5	8.8
TNG351	71.2	74.6	229	128	43,855	1.7	1	1.2	18.1
$LSD_{0.05}$	1.5	1.8	10	17	4,427	0.2	1	0.3	7.6

2. 77年秋作

7個地點之試驗結果，平均而言，在黃熟期至生理成熟期間收割，新品系中，H-7、E-7、E-8及 NKSI-1等均較對照種臺農351號高產。四個新品系青割鮮草產量比對照種臺農351號及臺南白分別高出11.3～7.7%及18.2～14.4%（表4）。區域試驗結果，竹東試區參試品系間並未有明顯差異存在，二林試區因靠近海邊，東北季風較強，各品系平均株高均較矮，致青割鮮草產量也較低，H-7 略高於臺農351號，惟差異不顯著。崙背試區H-7

表4. 77年秋作區域試驗各項農藝性狀之平均值

Table 4. Location mean of agronomic characters in regional yield trial of fall 1988.

Entry	Days to tasseling (day)	Days to silking (day)	Plant height (cm)	Ear height (cm)	Fresh weight (kg/ha)	Rust (1-5)	*H. turcicum* (1-5)	*H. maydis* (1-5)	Lodging (%)
H-7	66.8	70.6	200	88	49,894	1.6	1.8	1.6	4.9
E-7	65.2	69.5	212	87	50,858	1.2	2.0	1.6	5.5
E-8	66.5	70.5	207	93	51,564	1.4	2.0	1.6	3.7
NKSI-1	66.8	70.6	210	94	50,199	1.4	2.0	1.5	5.3
NKSI-2	66.9	70.7	212	95	48,523	1.3	1.6	1.5	7.5
NKSI-4	67.1	70.6	200	86	47,574	1.1	1.8	1.3	8.8
TN white	56.0	68.9	210	94	43,611	1.5	2.3	1.6	6.5
TNG351	66.6	70.2	206	95	46,314	1.7	2.0	1.6	6.4
$LSD_{0.05}$	1.4	1.3	9	7	4,211	0.4	0.4	0.2	3.2

青割鮮草產量高達72,261kg 較臺農351號之61,249kg 高出18%屏東試區 H-7之青割鮮草產量達50,238kg，比臺農351號之45,853kg 高出9.6%；新港及豐里試區，H-7公頃鮮草產量較臺農351號稍高；瑞穗試區各品系株高均較矮，青割產量也較差，H-7僅達28,288kg，而臺農351號爲25,957kg。

3. 78年春作

試驗結果，6個地點平均，以 H-7（農試所品系）及 NKSI-4（臺南場品系）兩者鮮草產量表現較高產，其中 H-7公頃鮮草產量高達51,369kg，較臺農351號之42,987kg 高出19.4%，較臺農1號之43,678kg 高出17.6%，而較臺南白之37,797kg 高出35.9%（表5）。區域試驗結果顯示。崙背試區 H-7之鮮草產量62,857kg ，較臺南白增加48.7%，較臺農351號增加18.4%，較臺農1號增加25.1%；新港試區，因大雨所有參試品系均或多或少有倒伏現象，H-7之產量仍達58,130kg，顯著高於臺南白、臺農351號及臺農1號。H-7鮮草產量顯著高過對照種臺農1號的地區尙有通霄及萬丹；H-7與臺農1號表現不相上下的試區則包括新豐及瑞穗。

表5. 78年春作區域試驗各項農藝性狀之平均值

Table 5. Location mean of agronomic characters in regional yield trial of spring 1989.

Entry	Days to tasseling (day)	Days to silking (day)	Plant height (cm)	Ear height (cm)	Fresh weight (kg/ha)	Rust (1-5)	*H. turcicum* (1-5)	*H. maydis* (1-5)	Lodging (%)
H-7	67.4	70.8	235	115	51,369	2.0	1.8	1.6	8.4
E-7	66.0	69.1	234	107	43,827	2.0	1.8	1.5	10.6
E-8	66.9	69.3	229	107	47,311	1.3	1.5	1.5	8.4
NKSI-1	66.0	69.6	228	110	47,402	2.1	2.1	2.0	9.4
NKSI-4	66.6	69.8	232	112	52,580	1.8	1.8	1.5	8.9
NKSI-7	67.2	70.5	238	123	46,727	1.8	1.7	1.5	8.4
TN white	65.0	69.1	222	112	37,797	1.8	1.8	1.8	11.6
TNG351	66.2	70.2	221	110	42,987	2.0	1.8	1.5	9.0
TNG1	66.1	69.8	236	113	43,687	2.0	2.0	1.5	9.1
$LSD_{0.05}$	1.5	1.2	11	10	5,493	0.5	0.4	0.4	2.2

4. 78年秋作

6個地區之平均，公頃鮮草產量以 H-7（農試所）及 Si-16（臺南場）兩者表現較佳，農試所品系 H-7公頃鮮草產量高達59,448kg，較臺農351號高出19.8%，較臺農1號超過17%，而銹病等級僅爲2.0，煤紋病爲1.2，葉斑病爲2.0，螟蟲爲害輕，倒伏少，較現有飼料玉米品種臺農351號及臺農1號爲優（表6）。區域試驗結果，芳苑試區 H-7與對照種臺農1號相近；崙背試區 H-7產量達73,938kg，較臺農1號增產30.7%，而銹病及煤紋病均較輕微；新港試區 H-7達82,130kg，顯著高於對照種臺農351號及臺農1號；萬丹試區 H-7產量顯著高於對照種，約增產19.7%；通霄、芳苑及瑞穗試區，H-7產量與臺農1號相若。

表6. 78年秋作區域試驗各項農藝性狀之平均值

Table 6. Location mean of agronomic characters in regional yield trial of fall 1989.

Entry	Days to tasseling (day)	Days to silking (day)	Plant height (cm)	Ear height (cm)	Fresh weight (kg/ha)	Rust (1-5)	*H. turcicum* (1-5)	*H. maydis* (1-5)	Lodging (%)
H-7	59.3	62.5	214	107	59,448	2.0	1.2	2.0	1.0
E-7	58.3	61.3	209	100	53,838	2.4	1.2	2.1	1.5
Si-7	58.7	62.6	196	94	51,787	2.3	1.3	2.4	1.5
Si-16	61.9	65.1	194	93	59,752	1.4	1.2	1.6	1.0
TNG351	58.6	60.7	200	102	49,625	2.6	1.3	2.4	1.5
TNG1	57.4	60.5	205	98	50,808	2.4	1.2	2.1	1.0
$LSD_{0.05}$	1.2	1.4	6	4	3,519	0.3	0.1	0.2	0.2

綜合兩年來區域試驗之總平均顯示， H-7公頃鮮草產量在52,537kg，較其他參試品系 E-7及 E-8爲優，且較對照種臺南白高出25.71%，較臺農351號增加15.4%，較臺農1號高出11.6%（表7）。

表7. 77年春作至78年秋作青割玉米新品系區域試驗之參試品系、參試期作數及公頃鮮草產量

Table 7. Mean fresh weight for entry and number of crop season involved in regional yield trials from spring 1988 to fall 1989.

Entry	Number of crop season	Fresh weight (kg/ha)	Entry	Number of crop season	Fresh weight (kg/ha)
H-7	4	52,537	NKSI-4	3	48,138
E-7	4	48,994	NKSI-7	1	46,724
E-8	3	48,543	Si-7	1	51,787
H-41	1	51,938	Si-16	1	59,751
NKSI-1	3	47,608	TN white	3	41,782
NKSI-2	2	47,474	TNG351	4	46,102
NKSI-3	1	45,134	TNG1	2	46,066

(四)穩定性分析

由於各年度所選擇的地點及品系不同，以致不能把所有地點及品系合併進行穩定性分析，僅分別以春作或秋作具共同參試品系之地點爲基礎進行穩定性分析。 H7在春作之開花期、株高，秋作之開花期、吐絲期、穗位高及鮮草產量均屬穩定。由 bi 值觀之，相較於臺農351號及臺南白， H-7在較好之環境下，具有較高之鮮草產量潛力。若以 cv 值觀之，春作 H-7開花期及吐絲期的 cv 值均略低於對照種；而株高、穗位高及鮮草產量之 cv 值則稍高於對照種臺農351號，但與臺南白相近。秋作 H-7不論在開花期、吐絲期、株高、穗位高及鮮草產量等性狀均比對照種臺農351號具有稍低之 cv 值（表8）。

表8. 各項農藝性狀穩定性分析之介值

Table 8. The stability parameter for five traits of seven entries in regional trials.

Crop season	Entry	Days to tasseling				Days to silking				Plant height			
		Mean	bi	Sd^2	cv	Mean	bi	Sd^2	cv	Mean	bi	Sd^2	cv
	H-7	69.5	0.95	0.41	7.4	72.2	0.91	0.59*	7.2	244.3	0.97	11.02	14.3
	E-7	68.6	0.96	1.68*	8.0	71.1	0.82	1.08**	7.0	237.5	1.16	30.06	16.9
	E-8	68.6	0.95	0.15	7.6	71.1	1.01	0.35	7.0	233.9	1.28	1.73	17.3
Spring	NKSI-1	68.1	0.86	0.72*	6.7	71.4	0.91	1.17**	6.4	230.3	0.85	44.32	13.9
	NKSI-4	69.2	0.90	0.01	7.4	72.3	0.94	0.46	7.3	234.0	1.03	14.55	14.4
	TNG351	69.2	1.11	0.04	8.5	71.8	1.16	0.42	7.8	227.3	0.75	21.59	11.8
	TN white	67.4	1.28	0.45	9.6	70.7	1.27	0.92**	8.7	236.0	0.96	40.51	16.3
	H-7	63.4	0.97	1.35**	12.7	66.9	0.92	0.50*	12.2	213.7	0.90	26.95	19.9
Fall	E-7	62.0	0.96	0.28	14.2	65.7	0.93	0.51**	13.2	217.0	1.07	13.32	22.7
	TNG351	62.7	1.07	2.01**	14.4	65.4	1.15	0.72**	13.0	205.9	1.03	34.51	21.8
Fall	SE	0.5	0.09	—	—	0.3	0.06	—	—	2.2	0.05	—	—
Spring	SE	0.3	0.07	—	—	0.4	0.10	—	—	2.2	0.07	—	—

表8. 各項農藝性狀穩定性分析之介值（續）

Table 8. The stability parameter for five traits of seven entries in regional trials.

Crop season	Entry	Ear height				Fresh weight			
		Mean	bi	Sd^2	cv	Mean	bi	Sd^2	cv
	H-7	123.7	1.15	5.99	22.0	51,964	1.38	672	18.7
	E-7	115.3	1.20	6.33	23.1	47,185	0.97	487	17.5
	E-8	116.4	1.23	62.54**	24.9	48,105	1.17	1,499	17.5
Spring	NKSI-1	113.0	0.74	25.95	17.3	47,115	1.07	189	16.7
	NKSI-4	115.2	0.76	34.65	17.5	50,485	1.02	2,250**	19.8
	TNG351	120.9	0.89	11.57	20.5	43,066	0.80	685	17.3
	TN white	123.8	1.02	96.20**	23.1	41,013	0.58	1,091	18.8
	H-7	102.7	0.93	19.69	31.5	55,931	1.02	981	30.2
Fall	E-7	98.9	0.98	13.79	31.7	53,371	1.11	770	31.9
	TNG351	102.9	1.08	23.82	31.7	48,024	0.87	578	31.5
Fall	SE	1.9	0.07	—	—	1,044	0.06	—	—
Spring	SE	2.6	0.13	—	—	1,401	0.20	—	—

*，** Significant at the 5% and 1% levels, respectively.

(五)臺農育 H-7 號之氮肥及密度試驗

本試驗之鮮草產量資料，裡作缺苗栗一個地點，又因花蓮之秋作及裡作僅有兩重複，加上各地點氣候及土壤因子差異極大，遂以期作及地點進行個別變方分析，分析結果顯示，氮肥處理效應差異達顯著者有春作之苗栗、嘉義，秋作之嘉義，裡作之彰化、嘉義。密度效應除春作之彰化及裡作之花蓮外，其餘均達顯著或極顯著。氮肥及密度之交感作用在秋作之苗栗爲顯著，而秋作之嘉義及裡作之彰化、嘉義爲極顯著。綜合本試驗之結果，顯示氮肥及密度對鮮草產量之影響隨地點及期作之不同而有差異，且氮肥與密度間之交感作用存在於秋作及裡作之某些地點。花蓮地區秋作及裡作較其他地區來得低產，主要係由於花蓮地區 9 月份以後多北季風強勁，天氣陰雨綿綿，晴天日數極少，不利於玉米之生長及光合作用。在磷肥及鉀，肥爲90：60 kg/ha 之施肥量下試驗，密度及氮肥之平均在多數期作及地點以 N_2（200kg/ha）、N_3（250

kg/ha），密度爲 D_1（70×15cm）下，鮮草產量表現較佳，故每公頃施用氮肥200～250kg 及種植密度爲70×15cm 之情況下， H-7 可得較高之鮮草產量（表9及10）。

表9. 臺農育 H-7 號在不同期作及地區下各級氮肥用量、栽培密度之小區鮮草產量之平均值（kg/10.5㎡）

Table 9. Influence of nitrogen and planting density on the fresh weight (kg/10.5㎡) of hybrid H-7.

Treatments	Spring				Fall				Winter		
	Changhwa	Miaoli	Hwalien	Chiayi	Changhwa	Miaoli	Hwalien	Chiayi	Changhwa	Hwalien	Chiayi
N_1	38.4	42.2	54.7	56.5	32.7	32.5	16.2	39.9	31.9	28.5	53.7
N_2	40.9	42.2	57.4	52.9	33.7	32.2	17.9	48.3	34.4	31.5	47.9
N_3	39.1	45.3	63.5	51.4	35.0	33.0	16.7	46.1	33.5	30.3	57.2
N_4	40.0	46.1	60.7	47.1	34.9	30.8	18.9	43.4	30.9	30.6	42.0
$LSD_{0.05}$	1.6	4.3	11.7	6.3	2.0	2.4	5.7	4.7	3.5	2.8	2.8
D_1	45.0	46.4	69.3	55.2	37.9	37.9	19.7	53.0	34.8	29.7	59.2
D_2	38.3	47.5	58.4	52.9	34.4	32.6	18.0	44.8	32.7	32.7	50.4
D_3	35.6	38.2	49.6	47.8	30.0	30.2	14.7	35.6	30.5	28.4	41.4
$LSD_{0.05}$	2.1	3.1	8.4	4.3	1.9	3.1	5.6	2.3	3.0	2.7	5.5

表10. 不同氮肥及栽植密度組合下臺農育 H-7 號在春、秋、裡作於各地區之小區鮮草產量（kg/10.5㎡）

Table 10. Forage yield (kg/10.5㎡) of H-7 in nitrogen and planting density trials.

Treatments	Spring				Fall				Winter		
	Changhwa (3/7)[z]	Miaoli (3/22)	Hwalien (3/9)	Chiayi (3/7)	Changhwa (8/17)	Miaoli (9/3)	Hwalien (8/18)	Chiayi (9/30)	Changhwa (9/22)	Hwalien (10/18)	Chiayi (10/24)
$N_1 \times D_1$[z]	41.8	46.2	64.7	54.6	36.3	34.8	16.8	39.7	34.8	27.0	66.0
$N_1 \times D_2$	36.5	45.4	53.4	62.2	32.8	30.9	19.0	49.6	31.8	33.6	50.3
$N_2 \times D_x$	37.0	35.1	46.1	52.8	29.0	31.8	12.9	30.4	29.0	25.0	44.9
$N_2 \times D_1$	45.5	42.9	70.9	59.5	38.5	33.7	20.1	62.8	35.3	31.0	55.2
$N_2 \times D_2$	38.8	47.1	59.1	51.4	34.3	34.5	19.4	44.7	33.5	34.8	49.2
$N_2 \times D_3$	38.5	36.7	42.1	47.7	28.3	28.5	14.2	37.5	34.3	28.7	39.3
$N_3 \times D_1$	47.5	46.7	73.1	58.7	38.3	35.2	20.5	57.3	37.0	29.6	71.9
$N_3 \times D_2$	40.7	47.2	62.6	52.2	35.5	31.9	15.0	48.8	32.5	29.7	58.8
$N_3 \times D_3$	29.0	42.1	54.9	43.2	31.3	31.8	14.7	32.2	31.0	31.5	41.1
$N_4 \times D_1$	45.0	49.6	68.4	47.8	38.5	30.9	21.4	52.0	32.0	31.0	43.6
$N_4 \times D_2$	37.3	50.3	58.5	45.8	34.8	32.9	18.6	36.2	33.0	32.6	43.2
$N_4 \times D_3$	37.8	38.8	55.4	47.6	31.3	28.7	16.8	42.1	27.8	28.2	39.2
$LSD_{0.05}$	1.9	3.7	5.3	5.0	2.7	2.0	3.5	5.6	3.3	4.2	2.7

[z] N_1, N2, N3 N4 represent nitrogen rate 150, 200, 250 and 300kg/ha, respectively.
D1, D2, D3 represent plant density 70×15cm (95,238 pt/ha), 70×20cm (71, 428 pt/ha) and 70×25cm (57, 143 pt/ha), respectively.
[y] Planting date are presented in parenthesis.

㈥臺農育 H-7 號與 XL678之青割產量比較試驗

81年春作吐絲後28天，果穗已達黃熟後期，接近生理成熟期，此時採收具有較高之整物率、果穗百分比及 TDN；當達吐絲後45天時，植株已完全乾枯，不適於取樣當作鮮草產量來比較（表11）。

表11. 1991年秋作，吐絲後28天之農藝性狀

Table 11. Agronomic characters measured at twenty-eight days after silking in fall of 1991

Planting date: 8, 29, 1991

Entry	Days to silking (day)	Fresh weight (kg/21m²)	Fresh weight (kg/ha)	Total dry weight (kg/21m²)	Total dry weight (kg/ha)	Whole-plant dry matter content (%)	Ear percentage (%)	TDN (%)	Digestible dry matter yield (kg/ha)
H-7	52	117.9	56,143	35.8	17,048	30.4	32.0	66.3	11,302
TNG1	53	107.1	51,000	34.1	16,238	31.8	30.3	66.0	10,717
XL678	59	128.7	61,286	36.5	17,381	28.6	23.7	63.0	10,950
$LSD_{0.05}$	3	5.8	2,762	3.6	1,714	4.9	4.1	1.0	560

80年秋作吐絲後28天，因天氣晴朗，光合作用充足，果穗已達適合採收時期（用手指擠壓，籽粒無乳汁流出），而81年秋作因陰雨天數極多，光合作用不足，故吐絲後45天才達黃熟期，相較之下，80年秋作吐絲後28天比81年秋作吐絲後45天，反而具有較大整株乾物率及乾重（表12及13）。

表12. 1992年春作，吐絲後28天之農藝性狀

Table 12. Agronomic characters measured at twenty-eight days after silking in spring of 1992

Planting date: 3, 24, 1992

Entry	Days to silking (day)	Fresh weight (kg/21m²)	Fresh weight (kg/ha)	Total dry weight (kg/21m²)	Total dry weight (kg/ha)	Whole-plant dry matter content (%)	Ear percentage (%)	TDN (%)	Digestible dry matter yield (kg/ha)
H-7	64.2	124.6	59,333	38.9	18,524	31.3	39.9	68.9	12,763
TNG1	65.7	123.8	58,953	38.6	18,381	31.1	37.8	68.4	12,573
XL678	72.5	129.8	61,809	40.6	19,333	31.3	24.6	64.8	12,527
$LSD_{0.05}$	1.2	5.4	2,571	3.6	1,714	1.6	5.4	1.6	452

表13. 1992年秋作，吐絲後45天之農藝性狀

Table 13. Agronomic characters measured at forty-five days after silking in fall of 1992

Planting date: 9, 23, 1992

Entry	Days to silking (day)	Fresh weight (kg/21m²)	Fresh weight (kg/ha)	Total dry weight (kg/21m²)	Total dry weight (kg/ha)	Whole-plant dry matter content (%)	Ear percentage (%)	TDN (%)	Digestible dry matter yield (kg/ha)
H-7	66.5	121.7	57,952	33.5	15,952	27.5	42.4	66.9	10,672
TNG1	66.5	103.2	49,143	28.2	13,428	27.3	45.3	67.7	9,091
XL678	76.5	127.7	60,809	34.9	16,619	27.3	37.4	65.6	10,902
$LSD_{0.05}$	1.9	6.2	2,953	3.3	1,571	2.7	4.6	1.7	911

綜合三期作之試驗成績，相較於 XL678， H-7約早熟7-14天，株高及穗位高較矮，乾物率、果穗比率及總營養消化率均稍高；鮮草產量則不及 XL678，但 H-7 可消化性之乾物產量則不亞於 XL678。

㈦抗病性檢定

1. 毒素病

本所及臺南場提供之青割玉米品系，經農試所植病系利用溫室苗期法檢定 B 型矮化嵌紋毒素病結果， H-7 接種 6 天後之感染率為33%，接種後13天則達100%，顯示 H-7 之病害指數為83%，較對照種臺農 1 號、臺農351號、臺南白及臺南 5 號之100%稍低，惟抗病等級仍歸為感(S)（表14）。

表14. 毒素病之人工接種檢定結果

Table 14. MDMV-B diseases resistance screened by artificial inoculation.

Entry	Susceptible percentage[z]			Diseases index	Resistant[y] level
	6 D.A.I.	13D.A.I.	18D.A.I.		
E-7	83	100	100	95	S
E-8	17	50	50	42	MR
H-7	33	100	100	83	S
H-41	50	100	100	88	S
TNG 1	100	100	100	100	S
TNG 351	100	100	100	100	S
TN white	100	100	100	100	S
TN 5	100	100	100	100	S

[z] D.A.I.: Days after inoculation.
[y] MR： (21-50%) ，MS： (51-80%) S： (81-100%) 。
(Data from reference 4) 。

2. 莖腐病

檢定結果， H-7 抗病性與臺農 1 號相同，親本 TA3651-377與 SW558之抗病性則較弱 (表15) 。

表15. 莖腐病之人工接種檢定結果

Table 15. Stem rot diseases resistance screened by artificial inoculation.

Entry	Susceptible plant/Total plant				
	Replication			Total	CK
	I	II	III		
TNG1	3/4	0/5	0/6	3/15	0/2
TA3651-377	5/5	4/4	5/5	14/14	0/5
ICAL210	4/4	4/4	4/4	12/12	0/3
SW558	4/4	1/5	5/5	10/14	0/4
H-7	4/5	1/4	0/5	5/14	0/6

(Data from C. H. Duan)

3. 銹病、葉斑病及煤紋病

普通型銹病之抗性檢定結果，親本 SW558爲極抗，TA3651-377爲感， H-7 比臺農 1 號及 XL678較具抗性。利用溫室人工接種檢定葉斑病結果， H-7 、SW558及 TA3651-377均爲感，而 XL678及臺農 1 號爲中抗。煤紋病之抗性檢定結果，SW558、TA3651-377 、 H 7 、臺農 1 號及 XL678亦均爲中抗 (表16) 。

表16. 銹病、葉斑病及煤紋病之檢定結果

Table 16. *P. sorghi, H. turcicum* and *H. maydis* resistance level screened by artificial inoculation.

Entry	*P. sorghi*	*H.turcicum*	*H.maydis*
SW558	HR (0)[z]	S (34.3)	MR (19.7)
TA3651-377	S (53.1)	S (32.8)	MR (18.3)
H-7	HR (0)	S (50.1)	MR (26.7)
TNG1	S (46.7)	MR (19.4)	MR (17.5)
XL678	MR (22.4)	MR (11.7)	MR (10.2)

[z] Resistance level : HR (0-5%) ，R (6-10%) ，MR (11-30%) ，S (31-60%) 及 HS (61-100%) ；括弧內爲罹病百分比 (病斑面積率) 。
(Data from W. H. Tsai)

4. 露菌病

82年秋作露菌病之發病情形， H-7 及親本 SW558、TA3651-377等均爲極抗；臺農 1 號爲抗；感病品種 TN5罹病率爲70～80%，抗病等級爲極感（表17）。

表17. 露菌病人工檢定之結果
Table 17. Downy Mildew resistance level screened by artificial inoculation.

Entry	Susceptible (%)			Resistance level
	I	II	III	
SW558	0	0	0	HR
TA3651-377	0	0	0	HR
H-7	0	0	0	HR
TNG1	13	11	0	R
TN5	70	80	80	HS

(Data from W. H. Tsai)

(八)抗蟲檢定（亞洲玉米螟）

田間檢定結果，春作 H-7 抗螟蟲（亞洲玉米螟）等級爲2.5介於其親本 TA3651-377（2.0）與 SW558（2.9）之間， H-7 與臺農 1 號之間並沒有顯著差異。秋作檢定結果，不論在輪生期或開花期，SW558及 TA3651-377對螟蟲抗性均爲 2 級，而 H-7 則爲 3 級， H-7、臺農 1 號及 XL678之抗性相似（表18）。

表18. 抗亞洲玉米螟之核定結果
Table 18. Asia borer resistance level screened by artificial inoculation.

Entry	Resistance level		
	Spring	Fall	
	Mean	Wheel	Tasseling
SW558	2.9	2.0	2.0
TA3651-377	2.0	2.0	2.0
H-7	2.5	3.0	3.0
TNG1	2.5	3.0	2.0
XL678	—	2.0	3.0

(Data from B. H. Chen)

(九)品質分析

青割玉米之青割適期，秋作宜於吐絲後35～45天，春作宜在吐絲後21～28天，一般以手指壓擠籽粒無乳汁流出時（黃熟期），即爲青割玉米收割適期[2]，此時之營養成分最高[10]。

青割玉米整株乾物所含營養成份與籽粒用玉米有明顯差異，以臺農 1 號及臺農育 H-7 爲材料，在青割收穫適期以整株青割作成青飼料，並與以籽粒爲飼料用的玉米比較營養價值，發現二供試品種青割用較飼料用高出約45%～200%乾物質產量，且佔有13～16%粗纖維含量，而飼料玉米籽粒內卻不含粗纖維，同時灰分含量也比較低。二個供試品種作爲青割用時，灰分含量約在3.4～4.7%，是飼料玉米籽粒內灰分含量的二至三倍[5]。然而飼料玉米籽粒含有 8～12%粗蛋白，3.9～5.2%粗脂肪及71～76%無氮抽出物（NFE），均顯著高於青割玉米，其中粗脂肪較青割玉米高出約 2～3 倍，粗蛋白質含量亦較青割玉米高38～76%，無氮抽出物（NFE）只較青割玉米高約11～21%。雖然飼料玉米籽粒之粗脂肪，粗蛋白及無氮抽出物（NFE）含量顯著高於青割玉米，但青割玉米卻含有飼料玉米所欠缺的粗纖維，高含量灰分及高乾物質產量。 H-7 當作青割玉米用時，在秋作營養成份之產量、粗脂肪、粗纖維、粗蛋白、無氮抽出物分別爲0.21、2.15、0.86及8.45ton/ha；春作分別爲0.25、2.00、0.89、7.71。而

當作飼料（籽粒）時，各種營養份之產量均較整株青割時來得少，因此就整體而言，青割玉米飼料價值較飼料玉米（籽粒）爲高（表19）。

表19. 臺農育 H-7 號與 TNG1作爲青割及飼料之乾物質營養成分比較

Table 19. The nutrient component of dry matter used as forage or field corn of TNG1 and H-7.

Entry	Crop season	Used	Moisture (%)	Moisture (t/ha)	Crude fat (%)	Crude fat (t/ha)	Crude fiber (%)	Crude fiber (t/ha)	Crude protein (%)	Crude protein (t/ha)	Ash (%)	Ash (t/ha)	NEF (%)	NEF (t/ha)	Dry matter (t/ha)
TNG1	Fall (1989)	Forage	6.85a*	0.91	1.74b	0.23	13.60a	1.81	6.42b	0.85	4.12a	0.55	67.26a	8.93	13.28a
		Field	10.67a	0.98	5.15a	0.47	trace b	trace	8.90a	0.81	2.00b	0.18	75.27a	6.88	9.14b
	Spring (1990)	Forage	8.45b	1.05	2.25b	0.28	16.63a	2.07	6.81b	0.85	4.24a	0.52	61.62b	7.66	12.44a
		Field	11.06a	0.58	4.81a	0.25	trace b	trace	11.25a	0.59	1.32b	0.07	74.66a	3.94	5.28b
H-7	Fall (1989)	Forage	7.82a	1.04	1.58b	0.21	16.14a	2.15	6.48b	0.86	4.65a	0.62	63.34b	8.45	13.34a
		Field	10.33a	0.70	3.90a	0.26	trace b	trace	9.69a	0.65	2.00b	0.13	76.07a	5.17	6.80b
	Spring (1990)	Forage	8.65a	1.07	1.98b	0.25	16.14a	2.00	7.22b	0.89	3.49a	0.43	62.26b	7.71	12.39a
		Field	11.43a	0.47	4.25a	0.17	trace b	trace	12.71a	0.52	1.30b	0.05	71.62a	2.94	4.10b

* Means followed by the same letter within each column of the same entry and crop season are not significantly difference at 5% level by the LSD test. (Data from reference 5)

青割玉米較飼料玉米富含粗纖維，主要來自營養器官莖稈、葉片及苞葉。臺農 1 號及 H-7 兩供試品種(糊熟期)中發現莖稈粗纖維含量在32～37%，葉片內的含量爲25～28%，而苞葉內粗纖維則在30～41%之間[5]。其他營養成分中，葉片粗蛋白質高達10～11%，幾乎與籽粒中粗蛋白質含量(9 ～11%)相當。二個供試品種秋作植株各部位粗脂肪含量在1.0～1.5之間，沒有明顯差異；但在春作植株，其籽粒內粗脂肪可達 3 %以上，葉片內粗脂肪含量仍維持在1.5左右，但稈及苞葉內粗脂肪卻明顯的減少。灰分方面，葉片灰分含量最高在7.0～12%，莖稈、苞葉及籽粒灰分含量變化不大，大約在2.0～4.0%之間。籽粒的 NFE 含量73～75%顯著高於莖稈、葉及苞葉(約在38～50%)。植株各部位水分含量變化不大，約在 8 ～12%之間(表20)。

表20. 臺農育 H-7 號與 TNG1 糊熟期植株各部位乾物質之營養成分比較

Table 20. The nutrient components of TNG-1 and H-7 in different plant parts.

Entry	Crop season	Plant part	Moisture (%)	Crude fat (%)	Crude fiber (%)	Crude protein (%)	Ash (%)	NEF (%)
TNG1	Fall (1989)	Stem	9.67b*	1.47a	37.00a	2.75c	3.30bc	45.81c
		Leaf	9.67b	1.65a	25.84b	11.61a	12.70a	38.44d
		Husk	9.83b	1.11a	33.00b	2.77c	4.00b	49.28b
		Kernel	10.83a	1.70a	trace c	10.04b	2.00c	75.40a
	Spring (1990)	Stem	8.67b	0.55c	37.33a	3.77c	3.70b	46.30b
		Leaf	9.12b	1.56b	28.53b	10.40a	9.15a	41.24b
		Husk	12.43a	0.33c	36.22ab	2.15d	2.63bc	46.23b
		Kernel	7.74b	3.81a	trace c	8.92b	1.59c	77.93a
H-7	Fall (1989)	Stem	11.00a	1.32a	32.67a	2.81c	2.00b	50.20b
		Leaf	9.00b	1.56a	28.53b	10.88a	10.70a	43.25c
		Husk	10.67a	0.93a	30.67a	4.23b	4.00b	49.46b
		Kernel	10.83a	1.35a	trace c	11.90a	2.00b	73.90a
	Spring (1990)	Stem	8.33a	0.73c	36.67a	3.90b	3.00b	47.37b
		Leaf	10.88a	1.82b	28.04b	10.28a	7.73a	41.25c
		Husk	9.52a	0.25c	41.11a	2.87b	2.28b	42.64bc
		Kernel	11.40a	3.18a	trace c	9.40a	2.70b	73.33a

* Means followed by the same letter within each column of the same entry and crop season are not significantly difference at 5% level by the LSD test.
(Data from reference 5)

青割玉米植株不同部位之營養成分不相同，玉米莖稈營養成分亦隨生育期發生不同的變化。在三個不同生育時期，經分析青割玉米莖稈飼料成份，發現二供試品種粗脂肪及粗蛋白質含量均隨著生育階段之漸趨完成而分別下降[5]。粗脂肪含量，臺農1號下降60%， H-7則下降74%；粗蛋白含量，臺農1號下降10%， H-7則下降19%。 H-7莖稈粗纖維與臺農1號莖稈粗蛋白質含量，雖然皆隨生育期而略有變化，但均未達顯著差異。二供試品種水分、灰分及無氮抽出物含量，在糊熟期與生理成熟期間分別爲8.33~8.67%、3.00~3.70%及47.37~51.10%，變化不大（表21）。

表21. 臺農育 H-7號與 TNG1 莖稈在不同生育階段乾物質之營養成分的變化

Table 21. The nutrient components of stem of TNG-1 and H-7 in different growth stages.

Entry	Growth	Moisture	Crude fat	Crude fiber	Crude protein	Ash	NEF
		%					
TNG1	Silking	9.50a*	1.48a	31.67b	3.92a	4.00a	49.44a
	Dough	8.67a	0.55b	37.33a	3.77a	3.70a	45.98a
	Physiology maturity	8.50a	0.38b	37.67a	3.50a	3.30a	46.65a
H-7	Silking	9.17a	0.92a	30.67a	4.04a	3.70a	51.83a
	Dought	8.33a	0.73a	36.67a	3.90a	3.00a	47.37b
	Physiology maturity	8.67a	0.36a	33.67a	2.50b	3.70a	51.10a

* Means followed by the same letter within each column of the same entry are not significantly difference at 5% level by the LSD test.
(Data from reference 5)。

臺農育 H-7號黃熟期植株各部位之百分比，在秋作葉、莖、果穗及苞葉分別爲22.1、22.1、51.2及4.5%；春作則分別爲24.7、24.7、47.1及3.9%[5]。兩期作之表現， H-7葉佔22.1~24.7%，略高於臺農1號之20.3~24.0%；莖22.2~25.3%亦高於臺農1號之17.8~21.8%；果穗47.1~51.2%，則稍低於臺農1號之50.0~56.8%；苞葉3.9~4.5%亦略低於臺農1號之4.1~5.1%（表22）。

表22. 臺農育 H-7號及臺農1號黃熟期植株各部位乾物質之百分比（%）

Table 22. The percentage of leaf, stem, ear and husk of TNG-1 and H-7 in dough stage.

Entry	Crop season	Leaf	Stem	Ear	Husk
TNG1	Fall (1989)	20.3	17.8	56.8	5.1
	Spring (1990)	24.0	24.0	50.0	4.1
H-7	Fall (1989)	22.1	22.1	51.2	4.5
	Spring (1990)	24.7	24.7	47.1	3.9

(Data from reference 5)

三、臺農育 H-7 號之特性

㈠植株性狀

莖色及葉鞘色：綠色

葉片色澤：深綠色

葉片數：15～16

花藥色：黃色

花絲色：淡紅色

穎　色：淡紅色

籽粒顏色：橘黃色

苞葉緊密度：緊密

每株穗數：1～2

籽粒行列數：14～16

㈡生長習性

播種後，發芽整齊、莖稈粗壯、株型高大、穗位與臺農351號及臺農 1 號高度相近，抗倒伏性強，開花與吐絲之間隔 2 ～ 3 天左右，果穗為 1 ～ 2 穗，鮮草產量高，在糊熟期至生理成熟期階段皆可收穫。

㈢生育日期

開花期及成熟期隨溫度高低變化甚大，播種至吐絲期，春作70天左右，秋作65天左右。生育日數，春作三月初播種至子粒生理成熟約106天，秋作八月底播種者約110天，適於本省耕作制度，隨著溫度下降，其生育日數延長。

㈣成熟期：中晚熟

㈤種植適期：春作 2 、 3 月間；秋作 8 、 9 月間；秋裡作10月初。

㈥適應土壤及地區：適合土層深厚且富含有機質，保水力強而排水良好之土壤，一般旱田及水田均可栽培。

㈦抗病性：臺農育 H-7 號對普通型銹病及露菌病具有高度抗性；煤紋病為中抗；不抗矮化嵌紋毒素病；莖腐病與臺農 1 號相同等級。

㈧產量：青割鮮草產量每公頃達50公噸，優於臺南白玉米或飼料玉米臺農351號及臺農 1 號。

四、參與育種人員名單

㈠主要人員：

1. 育種工作	臺省農業試驗所—謝光照、何千里、呂宗佳、劉孔生 盧煌勝
2. 區域試驗	臺灣省農業試驗所—何千里、謝光照
	桃園區農業改良場—林維和
	臺中區農業改良場—張隆仁、楊嘉凌
	臺南區農業改良場—曾清田、陳振耕
	高雄區農業改良場—鄭昭典
	臺東區農業改良場—林萬居
	花蓮區農業改良場—鄭書杏、簡文憲
3. 氮肥及密度試驗	桃園區農業改良場—林維和
	臺中區農業改良場—張隆仁、楊嘉凌
	臺南區農業改良場—曾清田、陳振耕

花蓮區農業改良場一鄭書杏、簡文憲

4. 資料整理　臺灣省農業試驗所一謝光照、盧煌勝

(二)相關人員：

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The Development of Tainung No.2 Maize-A Hybrid Cultivar for Forage Uses[1]

Guang-Jauh Shieh[2], Chan-Lee Ho[2], Tzong-Chia Lee[3], Kong-Sheng Liu[3] and Hung-Shung Lu[2]

Summary

Tainung No. 2 is a single-cross hybrid. Its parental inbreds are SW558 and TA3651-377. The maternal parent SW558 is a flint selected from the progenies of suwan-1 DMR which come from Thailand kasetsart University via inbreeding. SW558 is resistant to common rust, *H. turcicum* leaf blight and downy mildew, when it was screened under growth chamber conditions. The paternal parent TA3651-377 is a U. S. dent selected from the purified lines of Hi31, which was introduced from Hawaii University. TA3651-377 has high general combining ability (GCA) and is resistant to downy mildew and *H. turcicum.* Tainung No. 2 possesses 50 metric ton/ha forage yield potential, when harvest from dough to physiological maturity stages. It yielded higher than that of the TN white by25.7%, TNG351 by 14% and TNG-1 by 11.6% in two-year average. The days from planting to tasseling are 70 and 65 days in spring and fall crop seasons, respectively. The days from planting to maturity are 106 and 110 days, respectively, in spring and fall crops. Tainung No.2 is resistant to*Puccinia sorgi* (common rust) , *turcicum* and downy mildew, but immune from MDMV-B infection. The colour of stem and leaf shealth of Tainung No.2 are green, the leaf blade is dark green, the anther is yellow, the spikelets and silk are light red. The number of leaves per plant is 15-16, number of ear per plant is 1-2 and number of kernel rows per ear is 14-16. The husk covers the ear tightly. The kernel is dent type with orange color.

Key words : Forage maize, Dent, Flint.

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不同播種期對有限型及無限型大豆生育與產量的影響[1]

黃惠娟　曹文隆[2]

摘要：本研究以十個有限型及無限型的臺灣大豆栽培品種（系）爲材料，於1992年春作分三個時期（一月中旬、一月下旬及二月中旬）種植，進行播種期試驗，探討對植株農藝與產量性狀的影響。變方分析結果顯示兩種型態大豆品種之產量、營養生長日數、生殖生長日數、成熟期株高、營養生長（開花）期株高、有限型品種之生殖生長期間株高伸長長度、百粒重、有限型品種之節間長度及無限型品種之主莖莢數等性狀均受播種期之顯著影響，其餘產量性狀所受的影響則不顯著。較晚播種時，大豆各生育期日數的減少及生長程度的減緩，以有限型品種所受的影響較大；產量則以無限型品種的降幅較大，平均爲32.15%，有限型品種則爲18.85%。無限型品種晚播30日之減產幅度爲32.55%，晚播15日處理爲18.45%，主要原因在於晚播大豆的營養生長期縮短，可能致使供源能力降低，加上生殖生長期間亦縮短，且營養器官之生長與子粒充實同時進行，進而影響產量表現。本試驗結果建議在本省中部地區栽培大豆時，以一月中旬播種爲宜，如無法適時栽培，則宜愼選對播種時間適應性較廣的品種，以期獲得較穩定的收量。

關鍵詞：大豆、播種期、有限型、無限型、產量。

本省大豆栽培依期作可分爲春、夏作及秋裡作，由於各期作及地區的環境因子不同，加上大豆爲對環境敏感之作物，所以把握適當之播種時期爲栽培大豆穫至最佳收量的主要關鍵之一；在適當播種期內儘早播種可以提高產量，但若因氣候不良或管理上之決策，使得大豆無法適期種植，常造成產量的損失；而有報告指出不同基因型的生長習性，對產量的損失程度會有差異，如無限型的大豆品種，因晚植所造成的產量損失即小於有限型[8,9,14,15]。因此在非適期種植時，選擇減產程度較低者是非常重要的；況且臺灣目前大豆栽培以三年一作或二作之輪灌區爲主，且主要以春作時進行輪作，故爲了配合前、後作而有不同的播種期，所以進行不同生長型之品種的不同播種期試驗是有其必要的。

本試驗即以臺灣目前栽培之大豆品種（系），依生長習性分爲有限型及無限型兩種，於春作時以不同播種期種植，探討產量表現的差異，以及生育日數與產量組成相關性狀間之關係。

材料與方法

一、參試品種

有限型：高雄8號（Kaohsiung No. 8 - KS8）、臺農4號（Tainung No. 4 - TNG4）、臺農15號（Tainung No. 15 - TNG15）、農育7號（Nung-Yu No. 7 - NY7）、花蓮1號（Hualien No. 1 - HL1）、臺南選1號（Tainan Sel. No. 1 - TNS1）。

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無限型：高雄選10號（Kaohsiung Sel. No. 10 - KSS10）、百美豆（Palmetto）、和歌島（Wakashima）、中興2號（Chunghsing No. 2 - CH2）。

二、種植日期：

1992年1月17日（D_1）、1月31日（D_2）、2月15日（D_3）。

三、試驗設計：

採用裂區設計，種植日期爲主試因，品種爲副試因，各處理排列方式爲 RCBD。四重複，四行區，行長3公尺，行距55公分，株距15公分。

四、調查方法：

營養期：播種至小區內50%的植株至少開一花時日數，即開花期（Days to flowering）[12]；另 Fehr and Caviness[11]指出始花期（beginning bloom）爲主莖節上任何一節開一花時稱之，本實驗之調查採用開花期爲準。生殖期：開花期至成熟期日數。開花期及成熟期之株高：由子葉節量至莖頂。生殖期之株高：成熟期之株高減開花期之株高。成熟期：每小區95%以上植株莢果成熟。分枝數：每小區取樣五株之平均分枝數。主莖節數：每小區取樣五株之平均節數。節間長度：成熟期株高／節數。主莖莢數：每小區取樣五株之平均主莖莢數。分枝莢數：每小區取樣五株之平均分枝莢數。單株產量：每小區取樣五株之平均籽粒重。百粒重：種子含水率在13～15%時一百粒重量。

結果與討論

一、不同播種期對大豆各生育時期之影響

調查不同播種日期大豆之生育情形，發現有限及無限兩種生長型態的大豆營養生長（開花）期、生殖生長（開花至成熟）期、成熟期、營養生長期之株高與有限型生殖生長期之株高受播種期及品種（系）之影響呈顯著差異，且品種(系)與播種日期也有顯著之交感效應，而無限型生殖生長期株高則不受播種期之影響，也無品種(系)與播種期之交感效應。兩種生長型態品種(系)之成熟期株高並不受播種日期之影響，且播種日期與品種(系)之間也無交感效應(表1)，僅因品種不同而有所差異。

表1. 播種期對大豆品種生育影響之均方分析

Table 1. Mean squares of the planting-date effects on the growth characters of soybean cultivars.

Character	Plant type	Planting date (D)	Cultivar (C)	D×C	CV(%) of main Plot[z]	CV (%) of subplot[z]
Growth duration (day)						
Vegetative growth	Determinate	294.39*	37.39*	3.07*	0.76	1.19
	Indeterminate	88.27*	27.70*	7.97*	2.26	1.67
Reproductive growth	Determinate	159.39*	67.25*	30.01*	1.62	2.49
	Indeterminate	355.69*	109.47*	96.41*	2.98	2.21
Total	Determinate	876.29*	74.93*	37.93*	0.68	0.98
	Indeterminate	764.15*	228.39*	98.70*	1.04	0.96
Plant height (cm) at						
Initial blooming(IB)	Determinate	418.10*	206.02*	21.88*	6.62	7.44
	Indeterminate	363.15*	77.72*	38.20*	8.68	9.60
IB to maturity	Determinate	557.06*	2,095.86*	86.87*	38.64	25.58
	Indeterminate	529.40*	3,512.47*	64.12*	29.26	31.82
Maturity	Determinate	46.18	1,337.49*	143.16	24.36	20.94
	Indeterminate	128.81	4,395.70*	23.17	13.90	13.87

* Significant at 5% level.

[z] Main plot: planting date; subplot: cultivar.

另調查不同播種期對大豆生育日數之影響，不論有限型或無限型，較晚播種（D_2、D_3）大豆的營養生長期、生殖生期期及成熟日數均有減短之現象(表2)，此可由表1看出兩生長型態之三個生育時期均受播種日期、品種（系）及兩者交感效應的顯著影響。在營養生長期方面，D1 處理的生育日數明顯較 D_2、D_3 處理爲長，而 D_2 亦較 D_3 爲長，但差距不大。生殖生長期亦以 D_1 之生育日數較長，而 D_2 與 D_3 比較，除了無限型之 Palmetto、Wakashima 及CH2 之 D_3 處理分別較 D_2 處理多4.2、4.0及0.5天外，其餘的也以較晚播之 D_3 生育日數較短。成熟期的情況亦與生殖生長期相同，是爲 $D_1 > D_2 > D_3$，上述三個無限型品種之 D_3 較 D_2 分別多了2.7、0.5及0.5天（表2）。

由以上結果可知播種期之間的差距愈大（D_1 與 D_3，播種日期相差30天），其影響不同生育時段之生育數的長短亦愈大，差距較小者（D_1 與 D_2，D_2 與 D_3，播種日期相差15天），造成生育日數之差異則較小，主要是由於氣溫差距之影響，D_1、D_2 及 D_3 處理營養生長期之平均溫度分別爲14.9、16.9及18.8°C，生殖生長期之平均溫度分別爲21.9、22.7及24.4°C（資料來源：臺灣省農業試驗所農業氣象站），且在大豆營養生長期溫度愈高，促進花芽分化愈快，所以D_3之營養生育日數與 D_1 之差距最大。由表2可知不同播種期對大豆全程之生育日數的減少，以無限型較有限型所受的影響爲小。

表2. 播種期對不同大豆品種生育日數之影響

Table 2. Growth duration (day) of soybean cultivars affected by various planting date

Cultivar	Vegetative growth			Reproductive growth			Total		
	D_1[z]	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
Determinate type									
Kaohsiung 8	63.0	58.0	58.0	66.8	64.5	62.5	129.8	122.5	120.5
Tainung 4	65.0	61.3	58.3	66.8	62.0	62.3	131.8	122.8	119.8
Tainung 15	62.3	58.0	54.8	66.5	59.0	54.3	128.8	117.0	109.0
Nung-Yu 7	62.5	58.5	58.3	66.3	61.2	56.0	130.8	119.8	114.3
Hualien 1	62.8	61.8	60.0	65.5	59.0	57.8	131.5	123.0	122.3
Tainan S. 1	62.5	58.0	54.3	65.5	59.0	57.8	128.0	117.0	112.0
Indeterminate type									
Kaohsiung S. 10	62.5	58.3	54.3	66.5	64.8	64.3	129.0	122.5	121.0
Palmetto	65.8	61.0	60.0	62.5	57.8	62.0	127.5	118.8	121.5
Wakashima	63.0	58.3	54.8	66.8	61.5	65.5	129.8	119.8	120.3
Chunghsing 2	64.0	60.8	60.0	78.3	68.5	69.0	142.3	129.5	130.0

[z] Planting date D_1: 17 January; D_2: 31 January; D_3: 15 February.

大豆各生育時期之株高亦受不同播種期之影響，表3結果顯示有限型及無限型之 D_2 與 D_3 處理營養生長期株高均明顯較 D_1 處理爲矮，而生殖生長期株高除了TNG4之 D_1（17.3cm）較 D_2（14.5cm）多2.8cm外，其餘全部以較遲播種之 D_2 及 D_3較高，並且可以很明顯看出無限型生殖生長程度大於有限型，由表1已知兩型態品種（系）間之生殖生長程度受不同播種期的影響並不相同，有限型顯著受播種日期影響，而無限型則否，此乃因無限品種具有開花後主莖持續快速生長的特性所致，故不受播種期的影響。在成熟期株高方面，有限型之TNG4與YN7在 D_1 時期最高，TNG15、HL1、TNS1、Palmetto、Wakashima 及 CH2 六個品種則以在 D_2 播種時期之株高最高，而在 D_3 時期，有限型之 KS8及無限型之 KSS10爲最高，但已由表1得知不同播種期對成熟期株高所造成的差異並不顯著。

表3. 播種期對大豆品種生育期株高（cm）的影響

Table 3. Effects of planting date on plant height (cm) of soybean cultivars at different developmental stages

Cultivar	Initial Blooming(IB)			IB to maturity			Maturity		
	D_1[z]	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
Determinate type									
Kaohsiung 8	34.0	27.0	31.8	9.8	17.5	16.8	43.8	44.5	48.5
Tainung 4	40.0	32.0	34.3	17.3	14.5	21.0	57.3	46.5	52.8
Tainung 15	35.8	28.8	24.3	4.0	14.0	17.0	39.8	42.8	40.5
Nung-Yu 7	39.8	31.0	31.5	9.8	18.0	20.3	49.5	49.0	49.3
Hualien 1	41.0	32.5	35.0	6.0	25.6	14.5	47.0	58.3	49.5
Tainan S. 1	30.5	24.5	21.0	4.0	15.0	15.0	34.5	39.5	36.0
Indeterminate type									
Kaohsiung S. 10	32.5	25.0	21.8	29.8	30.8	32.0	62.3	56.8	63.0
Palmetto	38.5	30.8	34.8	34.3	54.3	41.8	72.3	85.0	76.5
Wakashima	37.5	32.3	21.8	12.3	30.3	26.8	49.8	62.5	48.5
Chunghsing 2	35.5	30.3	29.0	48.3	54.8	52.0	84.8	85.0	81.0

[z] Planting date D_1: mid January; D_2: late January; D_3: mid February.

大豆生育對環境因子的反應遠較其它作物敏感，尤其是日照的長短及強度；本試驗於1月中至2月中分三次播種，播種後至開花期前之營養生長期均爲短日照，可正常誘導開花（D_1 每日平均日照時數爲3.69hr/day, D_2 爲3.41 hr/day, D_3 爲3.10hr/day；平均日照強度 D_1 爲9.02 MJ, D_2 爲9.16 MJ D_3 爲8.70 MJ；資料來源：臺灣省農業試驗所農業氣象站，日照觀測方式以光電式進行[2]），此時期之日照對開花的影響並不大，三個播種期之日照時數在一定範圍內，且日照強度相近，較晚播種的 D_2 與 D_3 處理之營養生長期因而較短，此時期之株高亦較矮，而營養生長期的縮短常會使高產潛能受到抑制，進而影響籽粒產量。生殖生長期之生育日數同樣以 D_1 處理較長，故成熟期（營養生長期＋生殖生長期）所需日數亦以 D_1 處理最長。雖然營養生長期之株高以 D_2 與 D_3 處理矮於 D_1 處理，但前兩者之生殖生長程度則明顯的快於 D_1（表3），所以造成兩型態成熟期株高不受播種日期的影響；這種生殖生長期主莖快速增長的情況，無限型品種很明顯的大於有限型，此乃由於有限型品種在開花後主莖的生長延遲且節數不再增加，而無限型在開花後繼續生長分化，其節數與株高仍會增加。

二、不同播種期對大豆產量及產量組成相關性狀之影響

不同播種期對大豆產量及相關性狀之影響列於表4，其中播種期對二生長型態品種的產量及百粒重之影響呈顯著差異，不同品種（系）之間的差異亦呈顯著，而除無限型之百粒重外，亦有顯著的品種（系）與播種日期間的交感效應。而兩型態品種分枝數、主莖節數、節間長度、分枝莢數、主莖莢數等產量相關性狀，除無限型主莖莢數外，其餘均不受播種日期的影響。品種間除無限型之節間長度無差異外，其餘均呈顯著差異。另在播種期與品種（系）之間的交感效應方面，兩型生長型態之主莖莢數呈顯著交感，其餘性狀則無交感效應。

表4. 播種期對大豆產量及相關性狀影響之均方分析

Table 4. Mean squares of the planting date effects on the grain yield related characters of soybean cultivars

Character	Plant type	Planting date (D)	Cultivar (C)	D×C	CV(%) of main Plot[z]	CV (%) of subplot[z]
Grain yield (g)	Determinate	2,785.98*	2,977.49*	382.75*	20.36	79.20
	Indeterminate	4,315.63*	2,605.16*	803.95*	12.28	24.06
100-seed wt. (g)	Determinate	46.07*	124.61*	2.36*	3.78	5.33
	Indeterminate	24.34*	238.48*	2.25	5.66	6.72
Branch no./plant	Determinate	1.93	6.89*	3.08	21.04	16.98
	Indeterminate	9.98	9.80*	1.17	16.84	20.01
Mainstem node no.	Determinate	6.42	41.72*	4.86	11.64	16.23
	Indeterminate	1.30	151.97*	1.21	15.26	13.68
Internode length (cm)	Determinate	3.25	14.47*	1.77	22.08	22.16
	Indeterminate	3.03	8.43	1.30	18.06	21.01
Pod no./plant on branched	Determinate	19.38	621.15*	46.61	27.62	27.37
	Indeterminate	140.84	1,830.73*	69.72	33.22	33.53
Pod no./plant on mainstem	Determinate	13.07	131.00*	105.94*	8.96	23.00
	Indeterminate	14.94*	291.78*	112.01*	28.98	33.51

* Significant at 5% level.

z Main plot: planting date; subplot: cultivar.

表5爲十種大豆品種（系）受不同播種期所造成的產量差異情形，由表中可知產量隨播種期的延後而有降低的現象，除了 KS8及 NY7之 D_2 處理產量（分別爲每株80.15g 與75.88g）稍高於 D_1 處理之產量(分別爲每株76.60g 與66.38g)外，其餘所有的品種均以 D_1 播種的產量最高，較晚播種之 D_2 及 D_3 處理則有減產的趨勢，但只有有限型之 KS8、TNG15與 NY7及無限型之 KSS10與 CH2 的產量減少呈極顯著或顯著差異。以D_1 處理爲對照比較，發現 D_2 時期播種的只有 CH2 的減產（−44.13 g/plant）呈極顯著差異；而 D_3 與 D_1 比較，則 KS8、TNG15、NY7、KSS10及 CH2 品種（系）均有極顯著或顯著的減產。由表5可知，在本試驗中不同播種日期的差距大小，在15天左右對產量的損失平均爲18.45%，而播種期差距達30天者，所造成的產量損失則較嚴重，平均爲32.55%，此與不同播種期影響各時期生育日數的情形一致，差距30天者較15天者生育日數減少的程度大，故所造成的產量損失亦較大。

以本試驗而言，較晚播種所造成產量損失原因在於營養生長期及生殖生長期的縮短，易於導致莖葉生長不足，莢與子實的生長亦受到影響[7]，所以較晚播種的D_2 與 D_3 處理植株的供源能力減小，加上生殖生長期縮短造成籽粒充實期短且充實不良的情形，影響產量；此一推論可由兩型態品種百粒重受不同播種日期影響所造成的顯著差異得到證實（表4）。Carter and Boerma[10]亦指出較晚播種減產原因在於較短的營養生長期，同時成熟期與開花期之株高亦較矮；Beatty *et al.*[6]及 Weaver *et al.*[15]的播種期試驗亦指出營養生長期縮短使得高產潛能受到抑制，造成減產。在本省以往的播種期試驗中，1973年詹[3]在苗栗地區進行試驗，指出春作之播種期對產量有極顯著的影響，早播較晚播增產達99.4%，且早播之單株籽粒及種子重也顯著增加，但其株高呈顯著減少，主因晚播氣溫漸高，植株已有徒長現象；張[4]在本省東部進行之大豆新品系播種期試驗，指出75年春作四個播種期，較晚播種的二個時期之始花期及成熟期，均較前面二次播種期之天數減少，而株高因延遲播種而顯著升高，其亦認爲因溫度漸高所造成；而本試驗中不同播種的成熟期株高差異並不顯著，亦因此造成兩型態三

表5. 播種期對大豆品種產量的影響

Table 5. Effects of planting date on the grain yield of soybean cultivars

Cultivar	Grain yield (g/plant)			Difference		Mean	F	CV(%)
	D_1[z]	D_2	D_3	D_2-D_1	D_3-D_1	$(D_2+D_3)/2-D_1$		
Determinate type								
Kaohsiung 8	76.60	80.15	66.25	3.68	-10.20**	-3.26	16.49**	4.8
Tainung 4	89.05	79.07	79.75	-9.98	-9.30ns	-9.64	<1	29.3
Tainung 15	52.53	47.15	30.60	-5.38	-21.92**	-13.65	10.63*	16.1
Nung-Yu 7	66.38	75.88	44.22	9.50	-22.15*	-6.35	7.34*	19.3
Hualien 1	89.75	57.17	67.00	-32.58	-22.75ns	-27.67	5.04	23.3
Tainan S. 1	63.00	44.67	38.20	-18.33	-24.98ns	-21.67	2.55	27.4
Total	437.31	384.09	326.02	-53.09	-111.30	-82.24		
Ratio (%)	100.0			12.20	25.50	18.85		
Indeterminate type								
Kaohsiung S. 10	85.82	73.55	39.35	-12.27	-46.48**	-19.38	15.20**	18.7
Palmetto	90.53	61.28	74.50	-29.25	-16.05ns	-22.65	3.57	20.7
Wakashima	104.50	97.25	77.13	-7.03	-27.15ns	-17.09	2.84	18.0
Chunghsing 2	95.50	51.38	36.55	-44.13**	-58.95**	-51.54	19.46**	22.7
Total	376.35	283.46	227.53	-92.68	-148.63	-120.66		
Ratio (%)	100.0			24.70	39.60	32.15		
Average				18.45	32.55			

*, ** indicate significant at 5 and 1% levels, respectively.

z Planting date D_1: mid January; D_2: late January D_3: mid February.

三播種期之主莖節數的差異不顯著；此與 Parvez *et al.* 在南美洲進行播種期試驗，指出減產因素是由於株高降低，主莖節數減少，莢數亦因而減少(13)的結果不盡相同。Board 也曾報告晚植分枝數的減少，間接造成分枝節數與稔節數的減少(7)。

另由生長習性來看，D_2 處理有限型品種減產程度爲12.20%，無限型品種爲24.7%；D_3 處理有限型品種減產25.5%，無限型品種爲39.60%（表5），而若以品種別來看，有限型有三個品種及無限型有二個品種之減產呈極顯著（顯著）差異，故無限型對晚植所造成的減產情形並不小於有限型，D_2 處理高出12.5%，D_3 處理高出14.1%；此與 Parvez *et al.*(13)指出無論是有限型或無限型大豆品種，其產量並不受到播種日期之影響的結果相同，即兩種生長型態品種之減產程度並無差異性存在，只在品種之間有所差異。許多學者指出不同基因型大豆的生長型式各異，因此不同播種期所造成的產量差異程度會有所不同。本試驗中無限型品種的減產程度爲32.15%，高於有限型的18.85%，其原因可能在於臺灣春作環境下，無限型品種的開花期、結實期及有效充實期均較有限型品種爲長，且其莢及子實之乾物質生長量分配率較高，以及開花後需更多的同化產物供給營養器官生長及子實充實之需(1)，故在較晚播種使營養與生殖生育期縮短，進而影響主莖莢數減少的情形下，無限型品種之產量所受到的影響較大。另由表1可看出無限型品種的生殖生長期受不同播種期的顯著影響，但生殖期生長程度的影響卻不顯著，可知其高產潛能在同樣的生長速度，但較短的生育日數下被抑制，此由表4中無限型品種主莖莢數顯著減少可獲證實；且因無限型品種植株形態之特性，莢果大多集中在主莖上，分枝莢數較少，故分枝莢數之減少不呈顯著差異，但因主莖莢數減少，即造成單株產量降低。目前一般栽培品種在較晚播種的情況下均有減產現象(5)，故應選擇對播種日期適應性較廣的品種。而僅以本試驗結果而言，在春作若能選擇 TN4、HL1、百美豆或和歌島，除了早期播種有不錯的產量外，在較晚植時（2月中旬）所造成的減產程度亦較小。所以若因氣候或管理上因素而無法適期播種時，需愼選對產量影響程度小之適當品種，以期有穩定性之收量。

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Planting Date Effects on the Growth and Yield of Determinate and Indeterminate Soybeans[1]

Huey-Jiuan Huang and Wen-Long Tsaur[2]

Summary

This study was conducted in the spring crop season of 1992 to investigate the effect of planting date (mid-January, late January, and mid-February) on the development and yield of 10 determinate and indeterminate soybean cultivars. Combined analysis of variance indicated significant planting date effects on the following characters: grain yield, vegetative and reproductive growth duration, plant height at initial blooming and maturity, 100 seed weight, plant elongation during reproductive growth and average internode length for determinate cultivars, and pod number on main stem for indetrminate cultivars. The other yield characters were not affected significantly by planting date. In the case of late planting, yield decrease of the indeterminate cultivars (32.15%) was more prominent than that of the determinate cultivars (18.85%) . With a delay of planting by 15 and 30 days, the yield of indeterminate cultivars decreased 18.45 % and 32.55%, respectively. The main reasons were the shortening of vegetative which might reduce the growth of leaves and stems and hence the source ability. Furthermore, the simultaneous growth of vegtative organs and seeds during the reproductive growth period tended to affect the yield performance of the indeterminate cultivars. The proper time of planting soybeans in central Taiwan is suggested to be mid-January. If late-planting is inevitable, the selection of cultivars less sensitive to environmental impacts is strongly recommended.

Key words: Soybean, Planting Date, Determinate type, Indetermingate type, Yield.

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Effects of Corn Residues on Soybean Yield[1]

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Abstract : Field experiments were conducted to determine the corn (*Zea mays* L. cv. Tainung No.1) residues on the yield of the subsequent soybean [*Glycine max* (L.) Merr.] crops in 1992—1994. The results suggest that there is a beneficial effect in direct incorporation of corn residues into soil on soybean yield. Pod and grain yields of both Summer and Spring crops were significantly different in varieties and treatments in the study. For Nungyu 7, it showed that pod and grain yields of double amounts of corn residue were in average the highest among treatments in both crops. Pod and grain yields of 1993 were higher than that of 1992 in the summer growing season, but only grain yield of 1994 was superior than that of 1993 in the spring growing season. Grain yield increased by ca. 27 and 41% in average for the Summer and the Spring, respectively. Similar results were found for Kaohsiung sel. 10. It was 19 and 9% increase of grain yield for the Summer and the Spring, respectively. From the combined analysis of variance, 100-grain weight was the only yield component significant in residue treatments of two varieties in all years. Results of the correlation analysis showed that pod yield was the only factor positively correlated with grain yield in both varieties in both crops. This demonstrates that as pod yield increased, grain yield showed a corresponding increase.

Key words : Residue, Corn, Soybean, Yield, Environment, Crop season.

INTRODUCTION

The allelopathic effects of various perennial weeds and crops have been intensively studied [4, 5, 6, 7, 10, 17]. Plants influence each other growth by means of exudates [13], leachates from residues [8, 10], residues incorporated into the growing medium [2, 3, 5, 6], or residues in natural environment [14]. Lynch (1977) observed that acetic acid produced from anaerobic fermetation of wheat straw inhibited the growth of roots of barley seedling. Cochran *et al.* (1977) found that when residues of lentils, peas, wheat, and barley were spread over bare soil toxins were released which inhibited root growth of wheat seedling.

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On the other hand, plant residues are considerd to be good resources for enhancing soil properties and reducing soil erosion and as a reserve for crop nutrients [9, 11]. The storage and use of precipitation can be greatly improved through the proper management of plant residues from the previous crops [16, 19]. Such practices can also decrease the dependence of crop production on the declining groundwater supply [16]. Crops are benefited from the previous crop residues through the improvement of weed control and the availability of soil nutrients [1, 15, 18, 19].

Baldock and Musgrave (1980) and Shrader *et al.* (1966) pointed out that corn was benefited from proper rotations to increased availability of nitrogen. Yang *et al.* (1993) reported an increase of soybean yield when double amouts of chopped corn residues were incorporated into the soil. Later, Yang *et al.* (1994) further demonstrated that soybean yield was significantly improved as double amounts of corn residues were directly incorporated with soil after ear harvest. There is not certain, however, the existence of beneficial effects in varieties and the relative effects in years. The correlation of yield components with grain yield needs also to be established.

The objectives of this study were to confirm the results of the previous experiments and to determine whether there would be any relative difference of the magnitude of the benefit between cropping seasons and varieties. The effects of corn residue on the correlation of yield components with grain yield were also analyzed.

MATERIALS AND METHODS

The experiments were conducted on the experimental farm of Taiwan Agricultural Research Institute (TARI) at Wufeng, Taichung Hsien, Taiwan (ROC) in 1992-1994. The soil was a silt loam (fine-loamy, mixed, nonacid, hyperthermic, Fluvaquentic Dystrochrept). The organic matter of this soil varied from 1.55 to 1.90% and pH value was from 4.6 to 5.5 in the testing periods. Fertilizer Taifei-39 (N : P : K=12% : 18% : 12%) was applied at 400 kg/ha two weeks after planting. Weeds were controlled by handweeding and hoeing periodically and pesticides 1-naphthyl-N-methyl-carbamate (50% WP, 2.5 kg/ha) and Mn^{2+} 16%/Zn^{2+} 2%/Ethylene-bisdithiocarbamate ion 62% (80% WP, 2.5 kg/ha) were sprayed at flowering and between R5-R7 stages for pest control.

Experiments consisted of 2 soybean varieties and 4 residue treatments arranged in a randomized complete blook design with 4 replications. Data were subjected to analysis of variance and the Duncan multiple range test at the 5 and 1% probability levels. Because there was significant difference between varieties and residue treatments in nearly all years, yields and yield components were compared and discussed separately for differnt varieties in different crop seasons.

Soybean varieties, Nungyu 7 and Kaohsiung sel. 10, were obtained from Soybean Research Ladoratory of TARI and corn hybrid Tainung No.1 was purchased from Taiwan Seed Service at Shinshieh, Taichung Hsien. There were 4 residue treatments (Table 1). The full amount (X) of corn crop was planted at a rate of 57,100 plants/ha^{-1} and plant residues of the aboveground remaining were directly plowed into soil after ear removal. The soil was

plowed again a week before planting with a rotary. Separate plots were selected for not cropping corn in at least a year prior to the experiments. Planting and harvest dates varied according to seasonal conditions (Table 2).

Table 1. The residue treatments for studying the effect of direct incorporation of corn residues on soybean yield in 1992—1994.

Label	Treatment
CK	no corn residues incorporated into soil
X	full amount of corn residues (57,100 plants/ha) icorporated
2X	double amounts of corn residues incorporated
4X	quadruple amounts of corn residues incorporated

Table 2. Weather conditions during the growing seasons of soybeans, Nungyu 7 and Kaohsiung sel. 10, at the experimental farm of TARI, Taichung Hsien, Taiwan (1992—1994) .

Crop	Growing period	Heat sum	Precipitation	Irradiance	Sunshine Hour
		°C	mm	MJ m^{-2}	h
Summer					
1992	8/4 —11/4	2,310.8	679.0	1,206.18	457.7
1993	7/26—10/19	2,312.2	334.8	1,285.32	560.6
Mean		2,311.5	506.9	1,245.75	509.2
Spring					
1993	1/28—6/2	2,632.1	682.0	1,515.28	620.7
1994	1/17—5/23	2,585.6	504.5	1,367.22	438.9
Mean		2,608.9	593.3	1,441.25	529.8

The subplots were 4.5 m wide (8 rows) and 10.0 m long with row spacings of 0.55 m and planting density of 25 seeds/m. Yields of pod and grain (oven-dried at 35°C for 96 h) were estimated from the central two rows at harvest by hand. Yield components were determined at harvest by sampling 10 plants from the near rows. The weather data were obtained from the weather station of TARI (24°02' N, 120°40' E, elevation 85 m) as listed in Table 2.

RESULTS AND DISCUSSION

From Table 2, data showed that generally Summer crop had higher daily values but lower seasonal sums of temperature, precipitation, irradiance and sunshine hour than Spring crop. When compared with field performance of soybean, no simple relations between climatic factors and soybean yield under the influence of corn residues can be concluded. It is not surprising because environment as a whole is a complex of weather, soil, pests, and management practices. Any simple assumptions made and conclusions drawn from a natural system is too oversimplify to the issue.

Pod and grain yields of both Summer and Spring crops of soybean were significantly different in variery and treatment in the study (Table 3). The data were therefore analyzed separately according to variety in different treatments in different years. For Nungyu 7 (Table 4a), it showed that pod and grain yields were significantly increased when double amounts of corn residue incorporated into the soil and were in average the highest among treatments in both crops. Pod and grain yields of 1993 were higher than that of 1992 in the summer growing season, but only grain yield of 1994 was superior than that of 1993 in the spring growing season. Grain yield increased by ca. 27 and 41% in average for the Summer and the Spring, respectively. Thus in regard of yield increase, double amounts treatment obtained the highest value in Nungyu 7.

Similar results were found in variety Kaohsiung sel. 10 (Table 4b). It was 13—26 and 6—12% increase of grain yield in double amounts treatment for the Summer and the Spring, respectively. It is worth noting that full amount of residue made a considerable increase of yield in Spring 1993. The results confirm the findings as that reported by Yang *et al.* (1994). The present data further showed that, in addition to Kaohsiung sel. 10, Nungyu 7 obtained the same effects of residue treatments.

Table 3. Combined analysis of variance on the effects of direct incorporation of corn residues to the yields of soybeans, Nungyu 7 and Kaohsiung sel. 10, in the summer (1992—1993) and the spring (1992—1994) crops.

Crop season	S.V.	D.F.	Mean square	
			Pod yield	Grain yield
			kg ha^{-1}	
Summer	Block (B)/Y	6	61,751	51,042
	Year (Y)	1	148,871 **	34,318
	Variety (V)	1	2,815,264 **	630,436 **
	Treatment (T)	3	57,910 **	128,067 *
	Y×V	1	1,386,211 **	142,506 *
	Y×T	3	2,409	38,082
	Y×T	3	2,733	23,356
	Y×V×T	3	26,283	6,770
	Error	42	27,419	28,974
Spring	Block (B)/Y	6	2,754	8,168
	Year (Y)	1	2,441,406 **	3,932,289 **
	Variety (V)	1	2,335,548 **	514,448 **
	Treatment (T)	3	1,032,127 **	455,591 **
	Y×V	1	4,427,868 **	1,243,783 **
	Y×T	3	500,435 **	231,798 **
	Y×T	3	551,216 **	206,217 **
	Y×V×T	3	679,660 **	301,331 **
	Error	42	30,868	17,876

* and ** indicate significance at 5 and 1% levels, respectively。

Table 4a. Means for yields of soybean, Nungyu 7, under the effect of direct incorporation of corn residues in the summer (1992—1993) and the spring (1992—1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields	
			Pod	Grain
			kg ha^{-1}	
Summer	1992	CK	2,930 a	1,840 a
		X	3,270 a	1,840 a
		2X	3,280 a	1,930 a
		4X	3,210 a	1,760 a
	1993	CK	3,490 a	1,860 a
		X	3,810 a	1,990 a
		2X	4,020 a	2,020 a
		4X	3,750 a	2,060 a
Spring	1993	CK	3,050 a	1,680 a
		X	2,990 a	1,630 a
		2X	3,150 a	1,710 a
		4X	2,970 a	1,630 a
	1994	CK	2,160 c	1,390 c
		X	2,690 b	1,730 b
		2X	4,030 a	2,620 a
		4X	2,730 b	1,780 b

In a column of the same crop season, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 4b. Means for yields of soybean, Kaohsiung sel.10, under the effects of direct incorporation of corn residues in the summer (1992—1993) and the spring (1993—1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields	
			Pod	Grain
			kg ha^{-1}	
Summer	1992	CK	2,800 a	1,670 a
		X	3,060 a	1,720 a
		2X	3,300 a	1,890 a
		4X	3,010 a	1,670 a
	1993	CK	2,790 a	1,490 a
		X	3,130 a	1,710 a
		2X	3,230 a	1,880 a
		4X	3,070 a	1,680 a
Spring	1993	CK	2,810 a	1,490 a
		X	2,870 a	1,560 a
		2X	3,050 a	1,670 a
		4X	2,850 a	1,540 a
	1994	CK	3,700 b	2,230 b
		X	4,080 a	2,510 a
		2X	3,850 ab	2,370 ab
		4X	3,620 b	2,250 b

In a column of the same crop season, means followed by a common letter are not significantly different at the 5% level by DMRT。

By analyzing the yield components, results indicated that 100-grain weight was the only element significant in Year, Variety, and Treatment in both growing seasons (Table 5). In separately, 100-grain weight of Nungyu 7 increased considerably in Summer 1993 by residue treatments (Table 6a) while Kaohsiung sel. 10 was significant in the summer crops (Table 6b). It was shown that growth characters such as leaf number and leaf area were stimulated by corn residues as well [19].

Results of the correlation analysis among yields and yield components were summarized in (Table 7.) Pod yield was the only factor positively correlated with grain yield in both varieties in both growing seasons. This demonstrates that as pod yield increased, grain yield showed a corresponding increase. For the tested varieties, grain number per pod was negatively correlated with 100-grain weight for Kaohsiung sel. 10 but not for Nungyu 7 (Table 8a and 8b).

Table 5. Combined analysis of variance on the effect of direct incorporation of corn residues to the yield components of soybeans, Nungyu 7 and Kaohsiung sel.10, in the summer (1992—1993) and the spring (1993—1994) crops.

Crop season	S.V.	D.F.	Mean square		
			Pod no.	Grain no.	100-g wt
			no. pl^{-1}	no. pod^{-1}	g
Summer	Block (B)/Y	6	2.1094*	49.7258	0.0160
	Year (Y)	1	180.8353**	52.0202	5.0794**
	Variety (V)	1	60.0238**	790.3127**	0.0749*
	Treatment (T)	3	3.8995**	33.8902	0.0630*
	Y×V	1	49.9142**	835.9327**	0.9629**
	Y×T	3	0.6640	64.0093*	0.0457*
	Y×T	3	1.3778	0.6243	0.0214
	Y×V×T	3	1.8055*	12.9660	0.0280
	Error	42	0.3364	20.7235	0.0140
Spring	Block (B)/Y	6	39.7591*	0.0140	0.5415
	Year (Y)	1	374.4709**	13.0321**	100.5006**
	Variety (V)	1	540.1557**	0.0012	82.7645**
	Treatment (T)	3	21.9745	0.0086	3.1794*
	Y×V	1	106.2703**	0.1702**	12.5139**
	Y×T	3	15.4635	0.0253	0.8326
	Y×T	3	3.7288	0.0052	0.5113
	Y×V×T	3	9.9722	0.0056	0.5179
	Error	42	8.5398	0.0155	0.8776

* and ** indicate significance at 5 and 1% levels, respectively。

Table 6a. Means for yields components of soybean, Nungyu 7, under the effect of direct incorporation of corn residues in the summer (1992-1993) and the spring (1993-1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields components		
			Pod no.	Grain no.	100-g wt
			no./pl	no./pod	g
Summer	1992	CK	46.4 a	1.5 a	17.34 a
		X	42.6 a	1.5 a	17.76 a
		2X	50.4 a	1.5 a	18.23 a
		4X	42.7 a	1.4 a	18.25 a
	1993	CK	35.4 a	2.2 a	14.89 b
		X	42.7 a	2.3 a	17.30 a
		2X	39.7 a	2.5 a	16.51 a
		4X	41.5 a	2.2 a	16.49 a
Spring	1993	CK	26.0 a	2.3 a	17.05 a
		X	24.8 a	2.3 a	17.74 a
		2X	26.0 a	2.4 a	18.07 a
		4X	24.6 a	2.3 a	17.79 a
	1994	CK	25.5 a	1.4 a	20.47 a
		X	27.8 a	1.3 a	21.05 a
		2X	29.7 a	1.3 a	21.18 a
		4X	27.4 a	1.4 a	21.51 a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 6b. Means for yield components of soybean, Kaohsiung sel. 10, under the effects of direct incorporation of corn residues in the summer (1992—1993) and the spring (1993—1994) crops.

Crop season	Year (Y)	Treatment (T)	Yields components		
			Pod no.	Grain no.	100-g wt
			no./pl	no./pod	g
Summer	1992	CK	31.3 a	1.8 a	17.21 b
		X	30.5 a	1.8 a	17.60 ab
		2X	33.4 a	1.9 a	18.38 a
		4X	29.8 a	1.7 a	17.71 ab
	1993	CK	37.2 a	1.9 a	12.26 b
		X	41.5 a	2.1 a	11.93 b
		2X	41.5 a	2.2 a	12.64 ab
		4X	40.8 a	2.2 a	13.55 a
Spring	1993	CK	27.5 a	2.1 a	15.95 a
		X	27.7 a	2.3 a	16.00 a
		2X	31.7 a	2.2 a	17.25 a
		4X	27.5 a	2.2 a	15.88 a
	1994	CK	32.9 a	1.4 a	16.95 a
		X	37.9 a	1.4 a	18.52 a
		2X	35.9 a	1.4 a	18.19 a
		4X	37.3 a	1.5 a	17.92 a

In a column of the same crop seaeon, means followed by a common letter are not significantly different at the 5% level by DMRT。

Table 7. Correlation analysis among yields and yield components of soybean, Nungyu 7, and Kaohsiung sel. 10, under the effects of direct incorporation of corn residues in the summer (1992—1993) and the spring (1993—1994) crops.

Variable	Pod no.	Grain no.	100-g wt	Pod yield	Grain yield
Summer crop					
Pod no.	1.000	−0.128	−0.050	0.265	0.432
Grain no.		1.000	−0.538*	0.575*	0.295
100-g wt			1.000	0.184	0.378
Pod yield				1.000	0.858**
Grain yield					1.000
Spring crop					
Pod no.	1.000	−0.536*	−0.034	0.758**	0.778**
Grain no.		1.000	−0.700	−0.345	−0.629*
100-g wt			1.000	−0.028	0.275
Pod yield				1.000	0.940**
Grain yield					1.000

* and ** indicate significance at 5 and 1% levels, respectively.

Table 8a. Correlation analysis among yields and yield components of soybean, Nungyu 7, under the effects of direct incorporation of corn residues in the summer (1992-1993) and the spring (1993-1994) crops.

Variable	Pod no.	Grain no.	100-g wt	Pod yield	Grain yield
Summer crop					
Pod no.	1.000	−0.658	−0.793*	−0.519	−0.092
Grain no.		1.000	−0.725	0.910**	0.750*
100-g wt			1.000	−0.440	−0.292
Pod yield				1.000	0.811*
Grain yield					1.000
Spring crop					
Pod no.	1.000	−0.740	0.733	0.543	0.832*
Grain no.		1.000	−0.965**	0.085	−0.368
100-g wt			1.000	−0.058	0.382
Pod yield				1.000	0.894**
Grain yield					1.000

* and ** indicate significance at 5 and 1% levels, respectively.

Table 8b. Correlation analysis among yields and yield components of soybean, Kaohsiung sel. 10, under the effects of direct incorporation of corn residues in the summer (1992-1993) and the spring (1993-1994) crops.

Variable	Pod no.	Grain no.	100-g wt	Pod yield	Grain yield
Summer crop					
Pod no.	1.000	0.971**	−0.901**	0.293	0.094
Grain no.		1.000	−0.813*	0.384	0.195
100-g wt			1.000	0.068	0.273
Pod yield				1.000	0.876*
Grain yield					1.000
Spring crop					
Pod no.	1.000	−0.880*	0.976**	0.932**	0.946**
Grain no.		1.000	−0.808*	−0.955**	−0.967**
100-g wt			1.000	0.904**	0.907**
Pod yield				1.000	0.996**
Grain yield					1.000

* and ** indicate significance at 5 and 1% levels, respectively.

It is apparently from the results of this series of experiments, there is no negative effects of corn residues on the growth and yield of soybean up to quadruple amounts. In the routine field practice, therefore, incorporation of plant residues from the former corn crops before soybean is better than removal of them. Double amounts of residue is the best choice for yield concern, yet full amount treatment may also be selected when the production cost is taken into consideration.

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期作間玉米殘留物效應對大豆產量之影響[1]

楊純明[2] 張愛華[3] 黃昭興[2]

摘 要

本項研究係於1992—1994年在臺灣省農業試驗所農場進行田間試驗，以探討期作及年份間之玉米殘留物效應對大豆產量之影響。玉米（*Zea mays* L.）爲飼料玉米臺農一號，大豆〔*Glycine max*（L.）Merr.〕則爲高雄選十號及農育七號。當前作玉米收獲後，即依設計倍量將玉米植株地地上殘留物分置田面，直接以迴轉犁犁入土中，並於大豆播種前一週再予耕犁一次。殘留物計有0（對照組）、X（全倍量、相當於57,100株／公頃）、2X（兩倍量）、及4X（四倍量）等四種處理，期作分爲夏作及春作兩種。試驗顯示，直接將玉米植株殘留物混入土中對後作大豆產量具有正面作用。無論夏作或春作，莢果及籽粒產量在品種及處理間均呈現顯著差異，本文因此針對各別品種在不同期作及年份間進行分析與討論。對農育七號而言，處理間兩期作均以兩倍量殘留物對莢果及籽粒的增產效果最高；夏作時，1993年之莢果及籽粒產量皆高於1992年者；春作時，1994年之籽粒產量大於1993年者。兩倍量殘留物處理之籽粒產量在夏作及春作分別平均增產約27及41％。玉米殘留物對高雄選十號也具有類似增產效果，惟兩倍量殘留物處理之籽粒在夏作及春作分別平均增產19及 9 ％。從合併變方分析的結果發現，產量性狀中僅百粒重在品種、處理、及期作間同時顯著差異。而相關分析的資料則顯示，唯有莢果產量與籽粒產量在兩參試品種及期作間呈顯著正相關，即籽粒產量隨著莢果產量的增加而升高。

關鍵詞：殘留物、玉米、大豆、產量、環境、期作。

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Yield Loss in No-till Corn Due to Weed Interference and Environmental Impact[1]

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Abstract: Field experiments over 4 years (1991-1994) were conducted at Taiwan Agricultural Research Institute Experimental Farm to evaluate the effects of weed interference and environmental impact on yield loss of corn (*Zea mays* L. cv. Tainung No.1) under no-till condition. A significant effect was indicated in weeding treatments, environmental impact, and their interaction. Generally yields were reduced by 20% when multiple weed populations were allowed to interfere for 6 and 8 weeks after planting for the fall and the spring crops, respectively. Kernel yields were further reduced to 33 (Fall 1992) and 56% (Spring 1993), respectively, of weed-free plots in a full-season weed interference. Regression analysis showed that there was a linear relationship between weed dry weight and kernel yield. Yet, no such relationships were found between kernel yield and heat sum, precipitation, irradiance and sunshine hour, which implied a more complicated interactions than simple effects in environmental impact.

Key words: Corn, Yield, Weed interference, Environmental impact, Climatic factors, No-till.

INTRODUCTION

Corn is the major dryland crop sown on more than 80,000 ha annually for livestock forage and grain in Taiwan. In addition to the increase of yield potential and better quality, the decrease of production cost is another primary concern in producing this crop currently. No-till cultivation is one of the solutions while little works has been done to study the production strategy.

In no-till condition, weed and pest control as well as cultivation practices is the key to the success of crop management. Numerous reports have shown that yields were reduced if weeds were allowed to compete with crops in the field (1, 5, 6, 8, 10, 12). But there are few studies in the literature of the ecomomic threshold duration of weed interference by multiple species in no-till corn. Weeding effort can be greatly improved when control practice is applid at this critical period.

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Sheu and Chu (1991) reported that there was a 15% short of kernel yield yet the expenditure was 13% less in no-till corn. Yang *et al.* (1993b) showed that acceptable yield may be maintained when weed interference was less than 6 weeks after planting under no-till. The magnitude of yield loss across years by weed interference and the effects of climatic factors on yield potential, however, are needed to be clarified.

This study estimate the degree of corn yield loss under no-till attributable to weed interference by multiple weed infestations and compare the environmental impact on such deficiency. Whether yield potential is related to weed density and climatic factors is also analyzed.

MATERIALS AND METHODS

Experiments were conducted at the Taiwan Agricultural Research Institute (TARI), Taichung Hsien, Taiwan (ROC) in 1991-1994. The loam soil was a Fluvaquentic Dystrochrept with a pH of 5.3 and 1.44% organic matter. The experimental plots were layout more than 6 months before planting (Table 1) and weeds were naturally occurring populations (Table 2). Fertilizer (N-P_2O_5-K_2O) was applied at 60-90-60 kg/ha each crop and additional nitrogen was applied at 3, 6 and 9 weeks after planting at a rate of 30 kg/ha. Pesticide 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methyl-carbamate was applied on soil surface after planting at 30 kg/ha (3% granule) and was sprayed on the canopy using 40.64% fluid at 1.2 L/ha in both 5 and 7 weeks after planting.

Table 1. The experimental layout for studying weed interference on no-till corn, "Tainung No.1", in 1991-1994.

Label	Treatment
Weed-free	weed-free throughout the growing season
W-1	1-week weed interference after planting
W-2	2-week weed interference after planting
W-4	4-week weed interference after planting
W-6	6-week weed interference after planting
W-8	8-week weed interference after planting
W-10	10-week weed interference after planting
Weedy	weedy throughout the growing season

Table 2. Naturally occurring populations of weed species and their proportions (> =5%) surveyed at 50% of tasseling in no-till corn field in 1991—1994.

Crop season	Weed species	Proportion
		%
Fall 1991	*Aqeratum houstonianum* Miller	57.7
	Echinochloa Colonum (L.) Link	10.8
	Cyperus rotundus L.	6.8
	Eleusine indica (L.) Gaertn.	6.3
	Aqeratum conyzoides L.	6.3
Spring 1992	*Diqitaria* spp.	35.0
	Aqeratum houstonianum Miller	30.0
	Echinochloa Colonum (L.) Link	23.5
Fall 1992	*Diqitaria* spp.	47.5
	Ageratum houstonianum Miller	20.0
	Echinochloa colonum (L.) Link	17.5
Spring 1993	*Ageratum houstonianum* Miller	37.5
	Digitaria spp.	15.0
	Ageratum conyzoides L.	12.0
	Polygonum lapathifolium L.	5.0
Fall 1993	*Ageratum houstonianum* Miller	45.0
	Echinochloa colonum (L.) Link	20.0
	Echinochloa Crus-galli (Beauv.) L.	15.0
	Diqitaria spp.	10.5
Spring 1994	*Aqeratum houstonianum* Miller	59.5
	Digitaria spp.	11.0
	Ageratum conyzoides L.	10.0
	Chenopodium serotinum L.	8.5

Seeds of corn cultivar Tainung No.1 were planted 0.04 m deep and subplots size was 7.0 m by 5.5 m (8 rows) with row and plant distance of 0.7 and 0.25 m, respectively, by hand. Population density was 57,100 plants ha^{-1}.

A square meter of weeds were sampled from the weedy subplots periodically throughout the growing season and their dry weights were recorded after oven-dried at 80°C for 72 h. The center 2-3 rows of plants were taken at harvest and yields were estimated by dry weights of ear (without husk) and kernel. The yield index was calculated as yield from weed interference divided by yield from weed-free check. The weather data were obtained from the weather station located at the experimental farm of TARI (24°02′ N, 120°40′ E, elevation 85 m) (Table 3).

Table 3. Weather Conditions during the growing seasons of Corn, 'Tainung No.1', at the experimental farm of TARI, Taichung Hsien, Taiwan (1991—1994).

Crop	Growing season	Heat sum	Precipitation	Irradiance	Sunshine hour
		°C	mm	MJ m^{-2}	h
Fall					
1991	7/15-10/18	2,581.2	443.5	1,654.1	482.3
1992	7/15-10/8	2,319.3	755.0	1,167.3	434.1
1993	7/15-10/18	2,575.9	228.0	1,460.6	634.0
Mean		2,492.1	475.5	1,427.3	516.8
Spring					
1992	1/8-5/20	2,558.3	643.0	1,307.9	455.5
1993	2/2-6/4	2,612.3	702.0	1,449.3	567.2
1994	1/5-5/11	2,478.4	507.0	1,284.4	419.9
Mean		2,549.7	617.3	1,347.2	480.9

The experiment was arranged as a randomizd complete block design with 3 replications. Duration of weed interference ranged from 0 (weed-free), 1, 2, 4, 6, 8 and 10 weeks after planting to full-season (weedy). Weeds were removed by hand at the desired periods and the subplots were handweeding every 2 weeks to keep weed free since then. The growing periods over 4 years were listed in Table 3. Data were subjected to analysis of variance and the appropriate testing was applied for statistics.

RESULTS AND DISCUSSION

Information on the economic threshold period of weed control is required to develop an integrated weed management system [7, 13]. It provides evidence of the length of time weeds can remain in a crop before they interfere with crop growth and reduce yield [9]. Whether such critical period varied with crop seasons and years is interested to verified.

Analyses of variance over years indicated that the effects of weed interference (Treatment, T) and environmental impact (Year, Y) to corn yields (ear and kernel) were significant in both the fall and the spring crops in all years (Table 5). A significant year by treatment interaction was also found for all data. Thus, yields were analyzed and presented separated for each year and weeding treatment (Tables 6a and 6b). As indicated, weeding treatments affected kernel yield and the magnitude varied with years (the environmental impact). Within years, generally reductions in corn yields increased as the duration of weed interference increased. Also, weed dry weight (Table 4) was significantly negatively correlated with kernel yield, graph is plotted using weedy check results (Figure 1). The importance of the individual weed species on corn yield, however, needs to be further studied.

Table 4. Mean and standard deviation of dry weights of weeds collected from no-till weedy corn field during the growing seasons of 1991-1994.

Crop	Growing season	Dry weight of weeds
		g m^{-2}
Fall	1991	500.1± 68.5*
	1992	518.7±135.2
	1993	259.6± 35.7
	Mean	426.1
Spring	1992	364.5± 42.3
	1993	294.4± 39.1
	1994	237.2± 40.4
	Mean	298.7

* Value is averaged over samplings from the growing season.

Table 5. Combined analysis of variance on the yield of Corn, 'Tainung No.1', under no-till Condition (1991-1994) .

Crop	S.V.	D.F.	Mean square	
			Yield	
			Ear	Kernel
Fall	Block/Year	6	133,324	74,761
	Year(Y)	2	130,572,397 **	113,834,458 **
	Treatment(T)	7	4,731,545 **	4,793,954 **
	Y X T	14	982,744 **	638,149 **
	Error	42	160,565 **	106,946
Spring	Block/Year	6	72,625	117,987 *
	Year(Y)	2	15,295,616 **	10,008,609 **
	Treatment(T)	7	6,247,527 **	4,720,154 **
	Y X T	14	514,719 **	352,310 **
	Error	42	66,456	38,844

* and ** indicate significant at 5 and 1% levels, respectively.

Table 6a. Means for yields of corn, 'Tainung No.1', in the fall crop under no-till condition (1991-1993) .

Teratment(T)	Year (Y)			T-Mean
	1991	1992	1993	
	kg ha^{-1}			
Ear				
Weed-free	4,260 a	6,070 a	8,440 a	6,260
W-1	4,040 ab	5,360 b	8,100 ab	5,830
W-2	3,980 ab	4,670 c	7,960 ab	5,540
W-4	3,580 ab	4,890 bc	7,960 ab	5,480
W-6	3,400 bc	3,700 d	7,910 ab	5,000
W-8	3,440 bc	2,850 e	7,730 abc	4,670
W-10	3,310 bc	2,830 e	7,620 bc	4,590
Weedy	2,760 c	2,290 e	7,140 c	4,160
Y-Mean	3,600	4,080	7,860	5,180
Kernel				
Weed-free	3,580 a	4,790 a	7,450 a	5,270
W-1	3,320 ab	4,240 b	7,050 ab	4,870
W-2	3,270 ab	3,880 b	7,000 ab	4,720
W-4	2,860 bc	3,820 b	6,870 b	4,520
W-6	2,600 cd	2,460 c	6,860 b	3,970
W-8	2,610 cd	1,960 cd	6,580 bc	3,720
W-10	2,510 cd	1,990 cd	6,300 cd	3,600
Weedy	2,060 d	1,580 d	5,790 d	3,140
Y-Mean	2,850	3,090	6,740	4,230

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table 6b. Means for yields of corn, 'Tainung No.1', in the spring crop under no-till condition (1992-1994).

Teratment(T)	Year (Y) 1992	1993	1994	T-Mean
	.... kg ha^{-1}			
Ear				
Weed-free	5,230 a	6,410 a	7,100 a	6,250
W-1	5,330 a	6,390 a	6,920 ab	6,210
W-2	4,750 b	6,140 a	6,980 a	5,960
W-4	4,630 bc	6,140 a	6,780 ab	5,850
W-6	4,570 bc	6,050 a	6,480 b	5,700
W-8	4,260 cd	5,570 b	5,170 c	5,000
W-10	3,910 d	3,910 c	5,110 c	4,310
Weedy	3,980 d	3,700 c	4,780 c	4,150
Y-Mean	4,580	5,540	6,170	5,430
Kernel				
Weed-free	4,270 a	5,350 a	5,720 a	5,110
W-1	4,280 a	5,250 ab	5,660 a	5,060
W-2	3,860 b	5,080 ab	5,630 a	4,860
W-4	3,760 b	5,030 ab	5,500 a	4,760
W-6	3,660 b	4,960 b	5,130 b	4,580
W-8	3,300 c	4,550 c	4,060 c	3,970
W-10	3,110 c	3,160 d	4,000 c	3,420
Weedy	3,140 c	3,000 d	3,760 c	3,300
Y-Mean	3,670	4,550	4,930	4,380

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

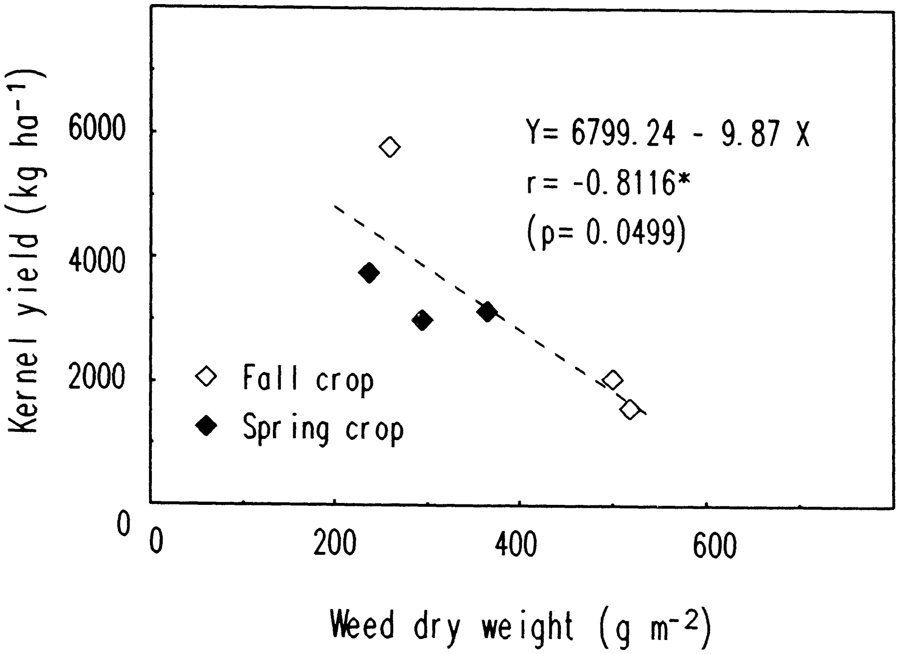

Fig. 1. Relationship between weed dry weight and kernel yield of weedy check of corn, Tainung No.1, under no-till condition in 1991-1994.

It showed that yields were reduced 20% when multiple weed populations were allowed to interfere for 6 and 8 weeks after planting for Fall and Spring, respectively (Figures 2a and 2b). The maximum reduction in corn ear and kernel yields were greater in Fall 1992 (62 and 67%) and Spring 1993 (42 and 44%) than in other years. The importance of weed interference duration to crop yields also has been reported in single weed species [1, 2, 3, 6, 9].

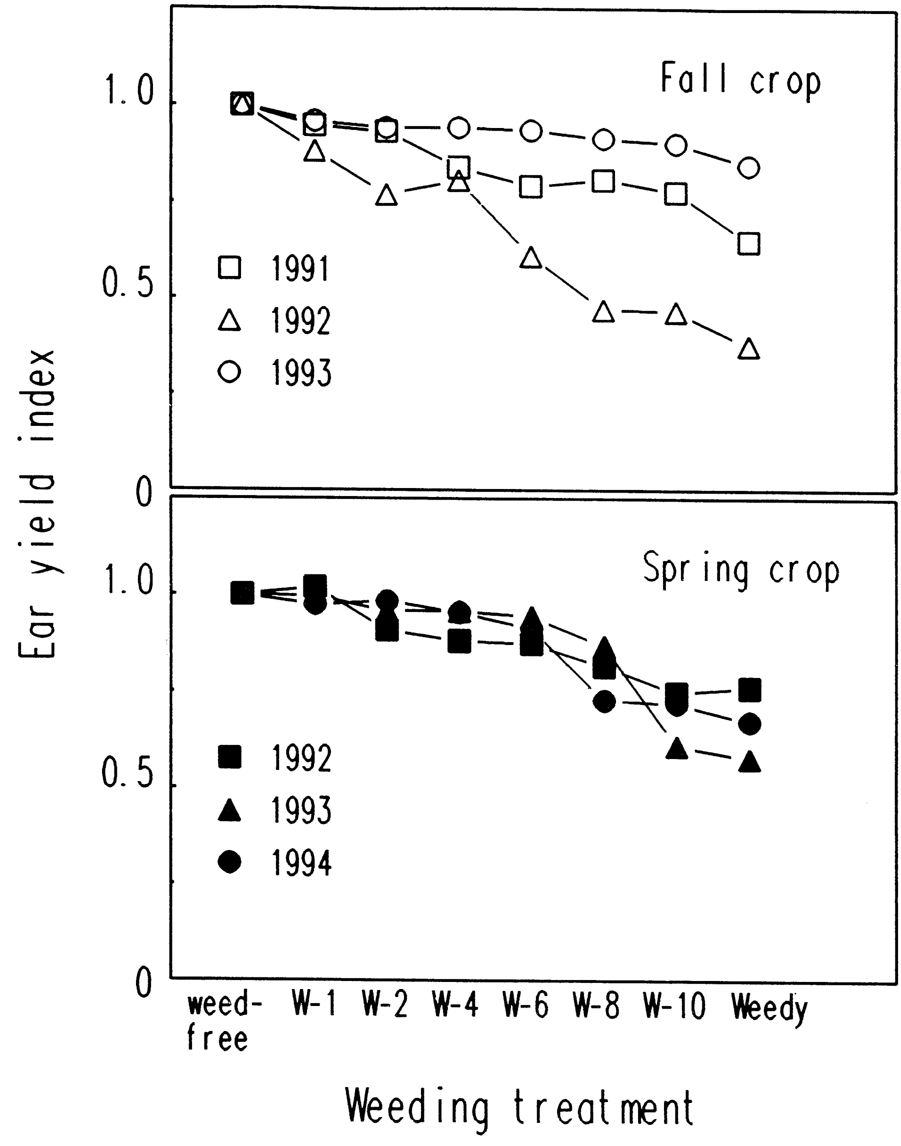

Fig. 2a. Effects of weeding treatment on ear yield index in the fall and the spring crops of corn, Tainung No.1, under no-till condition in 1991-1994.

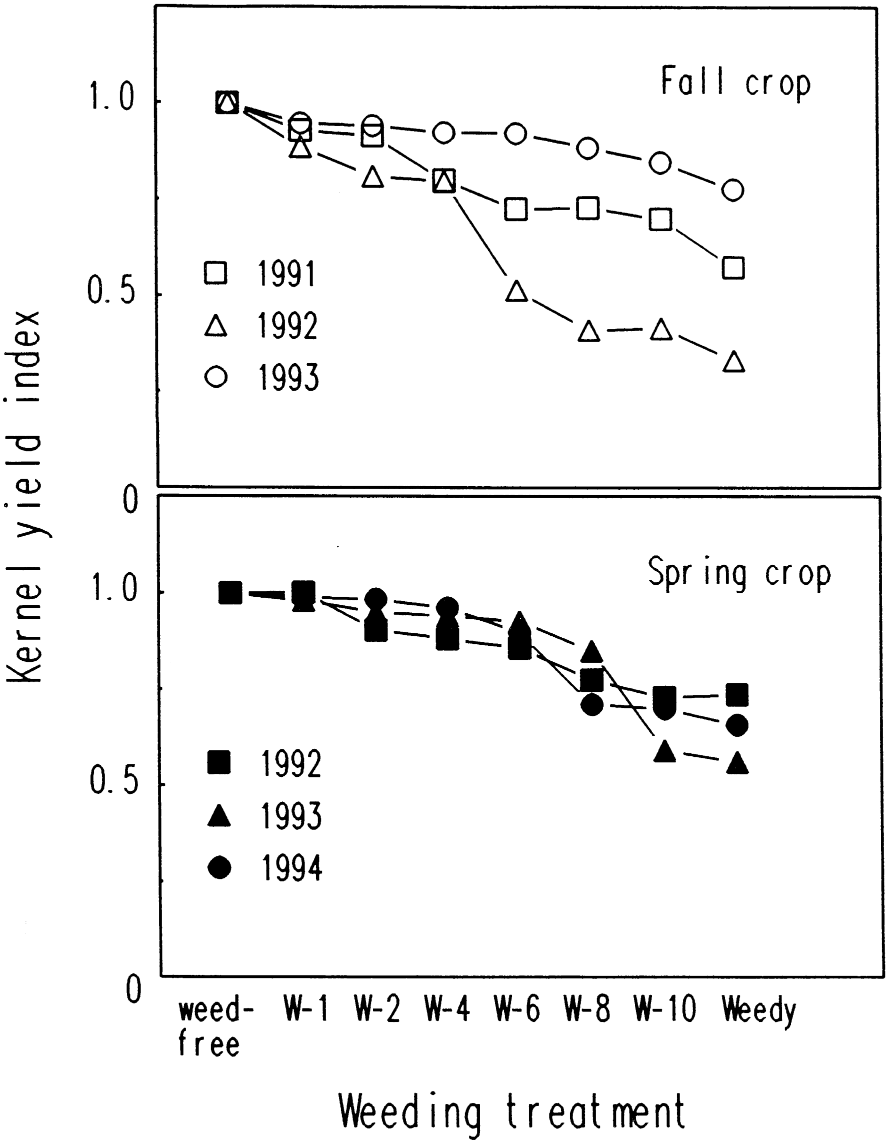

Fig. 2b. Effects of weeding treatment on kernel yield index in the fall and the spring crops of corn, Tainung No.1, under no-till condition in 1991-1994.

The previous report has shown the deleterious effect of multiple weed species, typically be faced by farmers, on no-till corn yields through the decreases of photosynthetic capacity (leaf area) and plant weight [12]. Hall *et al.* (1992) further pointed out that weed interference reduced corn leaf area by reducing the expanded leaf area of each individual leaf and accelerating senescence of lower leaves. The present study confirms the results and demonstrates that kernel yield was affected by weed density and can be lowered to less than 33%

(Fall crop) and 56% (Spring crop) of weed-free control for weedy check.

The weather conditions during the growing seasons of 1991-1994 were summarized in Table 3. It appeared that the growing period of Fall crops was shorter than Spring crops but the climatic factors were varied among growing seasons. By graphing the climatic factors with kernel yields of weed-free check, no simple linear relationships were established (Figure 3). A more complicated interactions among climatic factors rather than a simple one -to-one relationship is implied in delineating environmental impact. The result is no surprise since environment is the mixture of all variables as a whole and others such as soil properties, pests and weed species and densities may also exert great influence on corn growth and hence yield. The growth processes and yield mechanisms are so complicated that can not be correlated with a single factor. A more thorough study and analysis is required to clarify these relations.

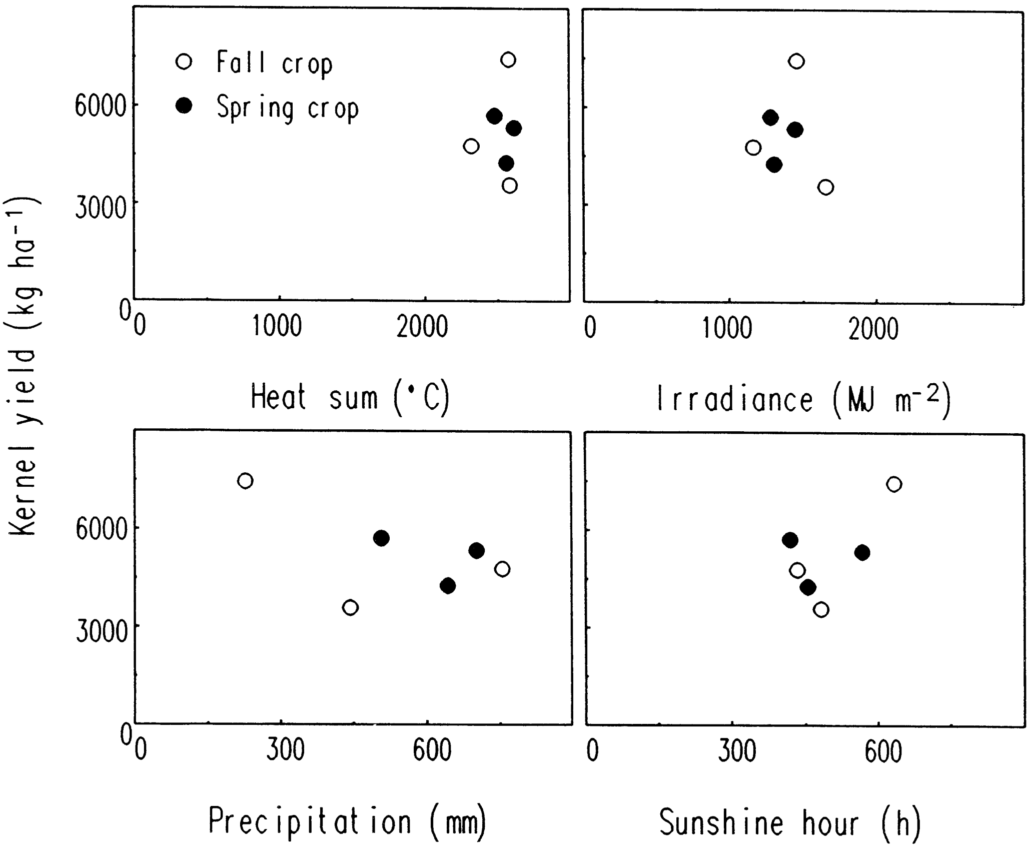

Fig. 3. Correlation between climatic factors and kernel yiels of weed-free check of corn, Tainung No.1, under no-till condition in 1991-1994.

As weed interference is proved to be a severe problem to no-till corn production, a cost effective weed control program is necessary and is recommended to be applied by 6 weeks after planting to prevent excessive yield loss.

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雜草干擾及環境效應對不整地栽培玉米減產之影響[1]

楊 純 明　　盧 煌 勝[2]

摘　要

本項研究係於1991-1994年在臺灣省農業試驗所農場進行田間試驗，以探討雜草干擾及環境效應對不整地栽培玉米減產之影響。參試品種爲飼料玉米臺農一號（*Zea mays* L. cv. Tainung No.1），雜草族群爲田間自然生長之不同種類者，除草措施則爲人工除草。雜草干擾處理計有八種，分別爲雜草干擾0（全期無草），1，2，4，6，8，及10週與全期雜草干擾等。根據試驗結果，雜草干擾時期長短、環境效應、及兩者交感均具有顯著差異。在試驗期間，大致上玉米之減產程度受到雜草干擾時期的影響。秋作雜草干擾六週、春作雜草干擾八週，玉米產量將減少約20％。全期雜草干擾最低可造成籽粒產量分別僅及全期無草處理區之33％（秋作）及56％（春作）。迴歸分析顯示，雜草乾重（雜草密度）與玉米籽粒產量呈直線關係，然而籽粒產量與全期熱位累積、降水量、日射量、及日照時數等氣象因子間並無此關係。顯然的，環境效應爲一多變因的複雜交感作用，玉米產量無法與個別氣象因子做出簡單的直線關係。

關鍵詞：玉米、產量、雜草干擾、環境效應、氣象因子、不整地。

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1. 臺灣省農業試驗所　研究報告第 1749 號。本研究承蒙行政院農業委員會補助試驗經費〔81-農建-12.2-糧-47(4)，82-科技-2.1-糧-33(4)，及83-科技-2.1-糧-11(4)〕，特此誌謝。
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灌水深度對芡實農藝性狀、產量及品質之影響[1]

徐原田[2]　劉新裕[2]　呂秀英[2]　劉慧瑛[3]

摘要：本研究以芡實爲材料，利用四種不同灌水深度之缽植方式栽培芡實，以探討灌水深度對芡實生長習性、產量及品質之影響，及改進芡實之栽培技術。試驗結果顯示，不同灌水深度對芡實各項農藝性狀之影響很大，在不同水深中以45cm之芡實各項農藝性狀之表現較佳，其柄長、葉長、葉寬、根長、根數、與全株鮮重之表現値甚高，且有最大之全株乾重，達11g/plant。所有與產量有關之性狀如芡實鮮重與乾重、百粒重、粒長、粒寬、粒數、乾殼重及乾仁重等之表現，均會隨著灌水深度之不同而有差異，四種水深中以45及60cm之芡實各項產量性狀之表現最佳，且皆顯著優於15及30cm處理者。在芡實之一般成分含量中，粗蛋白質及灰分受不同灌水深度之影響很大，除了灰分之外，芡實在45cm水深中各項一般成分之表現甚佳，其蛋白質含量高達13.6%。而P、K、Ca、Mg 及 Cu 之含量在不同灌水深度下，亦有顯著或極顯著之差異表現，一般以較淺之15及30cm水深中各項礦物元素含量之表現較佳，惟除了 Mg 之外，芡實在45cm水深中11項礦物元素含量之表現，與較淺之15或30cm水深者之差異不大，且大致皆較60cm略高。由上述兩年之試驗結果可知，45cm之灌水深度似爲栽培芡實之適當水深深度。此外，由芡實農藝性狀與產量性狀間之相關分析結果得知，除葉數與百粒重呈顯著負相關外，各農藝性狀之間大致都呈正相關，即柄愈茁壯，葉愈茂盛，根愈強健，全株之鮮重也愈大；各產量性狀間亦呈顯著正相關關係，即芡實愈大粒，粒數將較多，且愈重。

關鍵詞：芡實、水深、農藝性狀，產量、品質。

芡實（*Euryale ferox* Salisbury）屬睡蓮科（*Nymphaeaceae*）一年水生草本植物，『神農本草經』列爲上品，爲常用保健用生藥之一。有雞頭的別名，陶弘景認爲其莖上花似雞冠，故名雞頭。李時珍謂其可濟儉歉，故謂之芡。據本草記載，芡實有收斂、補脾、固腎、鎭痛、解暑熱及酒毒等作用，可治遺精、帶濁、濕痺、腰脊膝痛、小便失禁等症，常食可輕身、延年、益壽、強志及防老[123,6-9]。本省年需用量極多，惟大都仰賴進口。芡實爲民間四神湯材料之一[5,8,9]，爲健康食療補品，亦爲國際上之大衆化食品[11,14-16]，由於需要量頗大，在本省應屬具有發展潛力之特用作物之一。

芡實主要利用部份爲種子，惟其根、莖與葉亦供藥用。據資料指出[9]，芡實種子內含多種成分，每100g 中約含蛋白質4.4g、脂肪0.2g、碳水化合物32g、粗纖維0.4g、灰分0.5g、鈣9mg、磷110mg、鐵0.4mg、硫胺素0.04mg、核黃素0.08mg、尼克酸2.5mg。抗壞血酸6mg　及胡蘿蔔素微量。『中國藥材學』謂其蛋白質含量高達11.8%，且另含維他命　B_2及C等[6]。

芡實係水生植物，生於池沼湖泊中，分佈於大陸之黑龍江、吉林、遼寧、河北、河南、山東、山西、甘肅、江蘇、安徽、浙江、福建、江西、廣西、湖南、湖北、四川、廣東、雲南、貴州及臺灣等地，以及韓、日、德及印度等國[4,5,9-11,13-16]。早年先民自大陸來臺時引種入臺，初在鹿港試植，其後栽培擴及彰化全境，目前之栽植地區以彰化及雲林兩縣爲主，嘉義及臺南亦有栽培，多利用池沼低窪

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積水地區進行零星栽培[4,9,10]。筆者曾前往雲林海邊一帶瞭解芡實生產情形，多以池塘爲主，池水都很深，達60cm　以上，部分以急流水灌入區之生育較差，而以緩流水或適時補充水份者較佳[5]。數年前本所曾將芡實試植於蓄水式之缽內，以補充水分爲原則，發現芡實之生育頗佳。近年來由於養殖事業發展甚快，許多池塘改以養魚爲主，芡實亦被移栽於低窪水田或於積水地區種植，由於灌水深度不一，致芡實產量差異非常大，此問題常常困擾農民。本所有鑑於此，曾於1987年進行不同灌水深度試驗，初期結果尙佳，爲求資料較爲完整，於第二年繼續利用缽栽方式，探討不同灌水深度對芡實生長習性、產量及品質之影響，以改進芡實之栽培技術，所得結果將提供農民轉作與推廣之參考。

材料與方法

一、試驗材料：

芡實（*Euryale ferox* Salisbury）種子，種子購自彰化芡實產區。

二、試驗方法：

以不同灌水深度之缽植方式栽培芡實，四種水深依次爲15cm、30cm、45cm及60cm，塑膠缽直徑均爲50cm，高度依次爲35、50、65及80cm，每缽植二粒，待發芽成長至二葉片時，如有缺株即予補植，每缽僅留1株，每處理10缽。爲考慮可能有風向與陽光等之差異，田間試驗設計採 RCBD，4重複，試驗地點爲本所農場。缽內先裝入栽培腐植土（壤土：堆肥＝1：1），約20cm 高，於2月時播下種子。約十個月之生育期之施肥量爲每公頃氮肥80kg，磷肥144kg，鉀肥160kg。調查項目如下：柄長、葉長、葉寬、葉數、根長、根數、株鮮重、株乾重、芡實鮮重、百粒重、粒長、粒寬、粒數、芡實乾殼重、芡實乾仁重、芡實乾重。

採收適期及採收方法：據文獻[3,7,9,10]及初步觀察結果指出，芡實因開花時期頗不一致，其莖葉且被有多數棘刺，致使採收作業十分不便，故通常皆待其莖葉枯萎腐爛後，種子脫落於泥中，此時約在翌年一月間，亦即芡實之採收適期。採收方法可用竹製篩子自泥中撈起種子，予以洗淨晒乾。其種子可用切割機切成兩半，晒乾後分開仁與殼，所得之芡實仁即爲藥材商品，可包裝出售或貯藏。

芡實品質中一般成分之分析項目如下：水分、粗蛋白質、灰分、總醣、游離糖及粗澱粉之含量。進行成分分析前，先取乾燥之芡實仁樣品以磨粉機磨粉備用，分析時各精秤適當量，3重複。

(一)水分：精秤1g芡實仁粉末樣本，在105°C下乾燥過夜，秤至恆量，以乾燥前後重量之差異，計算其水分含量。

(二)粗蛋白質：精秤0.4g芡實仁粉末樣本，以 Semi-micro Kjeldahl 方法測出氮含量（N％），以N％×6.25表示之。

(三)灰分：精秤 1g 芡實仁粉末樣本，以600°C灰化法測定。

(四)總醣：將芡實仁粉末樣本以0.75N HCl 在沸水浴上迴流加熱2小時，以濾紙過濾殘渣，經水洗滌後，與水解液合併，以 Whatman GF/A玻璃棉濾紙過濾，並加水定量，濾液以酚一硫酸法測定總醣含量[12]，而以葡萄糖爲標準。

(五)游離糖：將芡實仁粉末樣本以約50倍之80％乙醇加熱（80～85°C），且迴流30分鐘，共萃取四次，殘渣以80％乙醇洗滌，並與前四次之萃取液合併，經玻璃棉濾紙過慮後，以酚一硫酸法測定糖含量[12]，而以葡萄糖爲標準。

(六)粗澱粉：將總糖含量減去游離糖含量後之數值乘以0.9，即爲粗澱粉含量。

(七)礦物質：芡實仁粉末樣本先經高溫（600°C）灰化，以 3N HCl 加熱溶解及蒸餾水稀釋後，用感應合耦電漿一原子發光光譜儀（Jobin-Yvon 38 TypeIII，inductivity coupled plasma atomic emission spectrophotometer）測定 P、Ca、Mg、Fe、Mn、Cu、Zn、B 及 Al 含量，以火焰光度計（Corning Model 400 flame photometer）測定 Na 及K之含量。

結果與討論

一、不同水深對芡實農藝性狀之影響：

由表 1 芡實農藝性狀之綜合變方分析結果得知，不同試驗年度（前後共兩年）下芡實各項農藝性狀之表現有差異；且除了根數之外，不同灌水深度對其他農藝性狀之影響，亦有顯著或極顯著之作用；此外，年度與灌水深度對葉寬有顯著之交感作用。由表 2 不同水深處理對芡實各項農藝性狀之個別差異比較結果可知，灌水愈深（45cm以上），芡實之柄長愈長，較15～30cm水深者長達19cm以上，但45cm及60cm之柄長差異則不顯著。在15cm之灌水深度下，芡實之葉長及葉寬最小，而葉數最多，較其他水深處理平均多出1.4葉；故提高灌水深度可使其葉片變大，而葉數減少。根長在30cm水深之表現較其他處理爲短，約短3～5cm。灌水深度不會影響芡實的根數表現，各處理之根數介於119～148之間。全株鮮重以30cm、45cm及60cm水深者最重，每株平均重達133g以上，惟其間之差異不顯著，而以15cm者最輕，只有116g。不同水深對芡實全株乾重之影響與全株鮮重之結果大致相同，惟60cm之全株乾重反略低於15cm（表 1 及表 2）。

表1. 芡實農藝性狀之綜合變方分析

Table 1. Combined analysis of variance of agronomic characters of *Euryale ferox* subjected to different watering depth

S. O. V.	D.F.	Mean square							
		Petiole	Leaf			Root		Plant	
			length	width	number	length	number	fr. wt.	dry wt.
Block(Y)	6	106	6	6	0.07	15	490	839	17.11*
Year(Y)	1	889*	2,061**	1,764**	9.03**	817**	27,848**	34,257**	96.61
Watering depth(D)	3	1,859**	38*	45**	3.78**	50**	1,544	3,445*	19.41*
Y*D	3	8	30	31*	0.03	5	173	72	0.05
Error	18	63	12	7	0.52	9	828	813	5.45

*, ** indicate significance at 5% and 1% levels, respectively.

表2. 不同灌水深度對芡實農藝性狀之影響

Table 2. Effect of different watering depth on the agronomic traits of *Euryale ferox*

Water depth (cm)	Petiole (cm)	Leaf			Root		Plant	
		length (cm)	width (cm)	number (NO.)	length (cm)	nunber (NO.)	fr. wt. (g/pl)	dry wt. (g/pl)
15	48.4c*	25.2b	24.7b	7.9a	32.2a	133.8a	116.1b	9.1ab
30	59.2b	30.1a	29.9a	6.5b	27.1b	118.5a	160.1a	10.6a
45	78.6a	29.3a	29.3a	6.5b	30.4a	148.0a	156.6 a	11.0a
60	79.6a	28.1ab	28.9a	6.5b	32.5a	147.3a	133.0ab	7.6b

* Means with the same letter of each column are not significantly different at 5% by the Duncan's multiple range test.

綜合上述結果可知，芡實在45cm水深中各項農藝性狀之表現甚佳，其柄長、葉長、葉寬、根長、根數、與全株鮮重之表現值甚高，且有最大之全株乾重。

二、不同水深對芡實產量性狀之影響：

不同灌水深度對芡實產量性狀之綜合變方分析結果列如表3，不同試驗年度對芡實鮮重與乾重、粒數、乾殼重及乾仁重之表現，有顯著或極顯著之影響。所有產量性狀如芡實鮮重與乾重、百粒重、粒長、粒寬、粒數、乾殼重及乾仁重等表現，均會隨著灌水深度之不同而有差異。年度與灌水深度對芡實乾重與乾殼重有顯著之交感作用。由表4之處理間個別差異之比較得知，此等與產量有關之性狀在灌水愈深時之表現值愈大，如在60cm 時芡實各項產量性狀之表現甚佳，其鮮重可達41.2g，乾重達14.9g，百粒重33.1g，粒長0.91cm，粒寬0.76cm，粒數112.5，乾殼重6.8g，及乾仁重7.3g，皆遠較15~30cm 水深者之表現為佳，惟45cm及60cm灌水深度間上述性狀之差異則不顯著（表3及表4）。

表3. 芡實產量性狀之綜合變方分析

Table 3. Combined analysis of variance of yield traits of *Euryale ferox* subjected to different watering depth

S.O.V.	D.F.	Mean square							
		Seed		100-seed	Seed			Seed coat	Seed inner
		fr. wt.	dry wt.	wt.	length	width	number	dry wt.	dry wt.
Block(Y)	6	37	10	25*	0.0012	0.0023	173	1	2
Year(Y)	1	490*	295**	20	0.0036	0.0003	2,707**	59**	69**
Watering depth (D)	3	2,199**	298**	344**	0.0456**	0.0262**	14,185**	67**	69**
Y*D	3	28	44**	18	0.0091	0.0059	266	9**	7
Error	18	54	7	9	0.0058	0.0037	530	2	3

*, ** indicate significance at 5% and 1% levels, respectively.

表4. 不同灌水深度對芡實產量性狀之影響

Table 4. Effect of different watering depth on the yield traits of *Euryale ferox*

Water depth (cm)	Seed		100-seed wt. (g)	Seed			Seed coat dry wt. (g/pl)	Seed inner dry wt. (g/pl)
	fr. wt. (g/pl)	dry wt. (g/pl)		length (cm)	width (cm)	number (NO.)		
15	6.8b*	2.6b	19.9c	0.76b	0.65b	33.5b	1.2b	1.3b
30	12.9b	4.8b	23.6b	0.78b	0.66b	49.6b	2.3b	2.5b
45	34.5a	13.2a	32.4a	0.88a	0.75a	114.6a	6.7a	6.5a
60	41.2a	14.9a	33.1a	0.91a	0.76a	112.5a	6.8a	7.3a

* Means with the same letter of each column are not significantly different at 5% by the Duncan's multiple range test.

綜合上述結果可知，芡實在45~60cm水深中各項產量性狀之表現甚佳，且皆顯著優於15~30cm處理組。

三、不同水深對芡實一般成分含量之影響：

由表 5 芡實一般成分含量之綜合變方分析結果得知，在各種成分含量中，其水分含量及粗蛋白質在不同試驗年度間之表現有差異；而粗蛋白質及灰分在不同灌水深度下之表現亦呈顯著差異。由表 6 不同水深處理之個別差異比較得知，粗蛋白質在15cm、30cm及45cm時之含量較高，三者均達13%以上，而以60cm之含量較少；灰分含量以30cm以下之灌水深度較多，約爲0.4～0.5%，45cm以上者較少。各處理間芡實之水分含量在9.4～10.6%之間，總糖量在70.1～74.2%之間，游離糖爲15%左右，粗澱粉在49.4～52.6%之間，其中之差異皆不顯著（表 5 及表 6）。

綜合上述結果可知，芡實爲含高澱粉及蛋白質之作物。而除了灰分略低之外，芡實在45 cm 水深中各項一般成分之表現甚佳，其游離糖、粗澱粉及粗蛋白質之含量均甚高。

表5. 芡實一般成分含量之綜合變方分析
Table 5. Combined analysis of variance of gross components of *Euryale ferox* subjected to different watering depth

S.O.V.	D.F.	Mean square					
		Moisture	Crude protein	Ash	Total sugar	Free sugar	Crude starch
Block(Y)	4	3.68	0.07	0.0070	16.37	1.99	10.35
Year(Y)	1	31.81*	3.72**	0.0015	60.55	2.55	30.76
Water depth (D)	3	1.82	1.18*	0.0220*	16.64	0.56	10.88
Y*D	3	2.99	0.10	0.0052	38.02	0.72	25.75
Error	12	2.85	0.32	0.0039	20.12	0.86	14.61

*, ** indicate significance at 5% and 1% levels, respectively.

表6. 不同灌水深度對芡實一般成分含量之影響
Table 6. Effect of different watering depth on the gross components of *Euryale ferox*

Water depth (cm)	Moisture (%)	Crude protein (%)	Ash (%)	Total sugar (%)	Free sugar (%)	Crude starch (%)
15	9.7a*	13.1ab	0.4a	72.6a	15.1a	51.8a
30	9.5a	13.8a	0.5a	70.1a	15.2 a	49.4a
45	10.6a	13.6a	0.3b	74.2a	15.8a	52.6a
60	9.4a	12.8b	0.3b	72.3a	15.6a	51.0a

* Means with the same letter of each column are not significantly different at 5% by the Duncan's multiple range test.

四、不同水深對芡實礦物元素含量之影響：

由表 7 芡實礦物元素含量之綜合變方分析結果得知，在各種礦物元素含量中 P、K、Ca 及 Zn 之含量在不同試驗年度之表現有差異；而 P、K、Ca、Mg 及 Cu之含量在不同灌水深度下，有顯著或極顯著之差異表現；此外，年度與灌水深度對 Mg 之含量有顯著之交感作用。由表 8 各處理間之個別差異比較結果得知，隨著灌水深度之增加，P、K、Ca、Mg 四種大量元素之含量均呈減少之趨勢，一般而言，以15～30cm水深之結果較佳，惟30cm與15cm間的差異不顯著；Fe、Cu、Zn、B 及 Al 等微量元素之含量，亦以15～30cm水深之結果較佳，惟 Mn 之含量，則以30～60cm水深之結

果較佳（表７及表８）。綜合上述結果可知，除了 Mn 之含量以60cm者最高外，芡實在較淺之15～30cm水深中其他各項礦物元素含量之表現較佳。此外，除了 Mg 之外，芡實在45cm水深中各項礦物元素含量之表現，與較淺之15～30cm水深者之差異不大，且大致較60cm者略高。

表7. 芡實礦物元素含量之綑合變方分析

Table 7. Combined analysis of variance of mineral elements of *Euryale ferox* subjected to different watering depth

S.O.V.	D.F.	Mean square										
		P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B	Al
Block(Y)	4	64	281	9	19.00**	18.04	1.39	0.04	0.022	0.03	0.004	0.51
Year(Y)	1	513*	5,797*	950**	0.38	42.67	5.01	0.05	0.001	0.25*	0.018	0.41
Water depth (D)	3	432*	1,322**	62*	17.82**	32.50	2.36	0.07	0.060*	0.01	0.002	0.52
Y*D	3	114	172	11	13.04*	41.89	1.34	0.06	0.014	0.04	0.003	0.41
Error	12	104	122	17	2.22	24.82	0.75	0.02	0.012	0.02	0.003	0.23

*, ** indicate significance at 5% and 1% levels, respectively.

表8. 不同灌水深度對芡實礦物質元素含量之影響

Table 8. Effect of dfferent watering depth on the mineral elements of *Euryale ferox*

Water dep. (cm)	P	K	Ca	Mg	Na	FE	Mn	Cu	Zn	B	Al
	mg/100g										
15	179.0ab*	156.3a	30.0a	24.7a	32.8a	3.75a	1.17b	0.41a	1.16a	0.26a	2.57a
30	183.8a	143.7ab	27.5ab	25.0a	31.7a	2.67ab	1.33ab	0.32ab	1.05a	0.24a	2.43ab
45	169.8bc	136.0b	23.8b	23.3b	32.2a	2.30b	1.34ab	0.23b	1.08a	0.24a	2.16ab
60	165.2c	120.8c	23.2b	21.5b	27.7a	2.67ab	1.42a	0.18b	1.09a	0.22a	1.90b

* Means with the same letter of each column are not significantly different at 5% by the Duncan's multiple range test.

五、芡實各性狀間之相關分析：

由表９芡實農藝性狀與產量性狀間之相關分析結果得知，除葉數與百粒重呈顯著負相關外，各農藝性狀之間大致都呈正相關，即梗愈茁壯，葉愈茂盛，根愈強健，全株之鮮重也愈大；各產量性狀間亦呈顯著正相關關係，即芡實愈大粒，粒數較多，且愈重。而芡實之梗愈長，葉形愈大，根長愈長，及根數增加，這些都能提高芡實之產量如芡實乾殼重、芡實乾仁重及芡實乾重；但葉數或全株鮮重與產量性狀間則無明顯之關係。由此可知，如能使植株生長強健，當可提高芡實產量。芡實之一般成分含量與礦物元素間之相關分析結果列如表10，除粗澱粉與總醣有極顯著正相關之外，其他成分或各種礦物元素之間，亦存有若干顯著或非常顯著之相關關係。

表9. 芡實各農藝性狀與產量性狀間之相關分析

Table 9. Correlation analysis among different agronomic and yield traits of *Euryale ferox*

Character	PL	LL	LW	LN	RL	RN	PFW	PDW	SFW	SW	SL	SWI	SN	CDW	IDW
Petiole length (PL)															
Leaf length (LL)	0.42*														
Leaf width (LW)	0.43*	0.96**													
Leaf No. (LN)	-0.06	0.37*	0.33												
Root length (RL)	0.42*	0.74**	0.72**	0.61*											
Root No. (RN)	0.59**	0.77**	0.73**	0.55**	0.88**										
Plant fr. wt. (PFW)	0.48**	0.84**	0.82**	0.27	0.63**	0.78**									
Plant d. wt. (PDW)	0.34	0.61**	0.57**	0.37*	0.51**	0.66**	0.85**								
Seed fr. wt. (SFW)	0.80**	0.29	0.33	-0.21	0.27	0.32	0.19	-0.07							
100-seed wt. (SW)	0.66**	0.24	0.28	-0.38*	0.16	0.26	0.25	-0.01	0.83**						
Seed length (SL)	0.63**	0.16	0.19	-0.10	0.14	0.24	0.15	-0.03	0.74**	0.70**					
Seed width (SWI)	0.64**	0.03	0.05	-0.08	0.05	0.23	0.10	0.01	0.67**	0.64**	0.89**				
Seed No. (SN)	0.79**	0.26	0.28	-0.21	0.23	0.29	0.19	-0.01	0.96**	0.79**	0.65**	0.60**			
Coat d. wt. (CDW)	0.75**	0.47**	0.53**	-0.06	0.38*	0.44*	0.34	0.07	0.92**	0.77**	0.77**	0.65**	0.87**		
Inner d. wt (IDW)	0.69**	0.47**	0.53**	-0.08	0.35*	0.39*	0.30	-0.01	0.90**	0.75**	0.75**	0.60**	0.84**	0.97**	
Seed d. wt. (SDW)	0.72**	0.48**	0.54**	-0.06	0.41*	0.43*	0.32	0.02	0.92**	0.76**	0.74**	0.61**	0.85**	0.98**	0.97**

*, ** indicate significance at 5% and 1% levels, respectively.

表10. 芡實一般成份與礦物元素間之相關分析

Table 10. Correlation analysis among gross components and mineral elements of *Euryale ferox*

	Moisture	Crude protein	Ash	Total sugar	Free sugar	Crude starch	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
Crude protein	-0.16															
Ash	0.12	0.27														
Total sugar	0.22	-0.09	-0.33													
Free sugar	-0.02	-0.22	-0.23	0.50*												
Crude starch	0.25	-0.04	-0.31	0.98**	0.32											
P	-0.36	0.59**	0.49*	-0.34	-0.33	-0.30										
K	-0.40	0.51*	0.36	-0.39	-0.28	-0.37	0.59**									
Ca	-0.46*	0.40	0.32	-0.40	-0.36	-0.35	0.45*	0.80**								
Mg	0.10	0.18	0.71**	-0.04	0.09	-0.07	0.42*	0.40	0.38							
Na	0.22	0.37	0.30	-0.17	-0.38	-0.10	0.31	0.56**	0.46*	0.39						
Fe	-0.22	0.11	0.47*	-0.02	-0.02	-0.02	0.09	0.40*	0.54**	0.51*	0.26					
Mn	-0.31	0.15	-0.11	0.27	0.25	0.24	0.08	-0.18	0.13	0.13	-0.04	0.06				
Cu	0.06	0.14	0.46*	-0.19	-0.24	-0.15	0.29	0.45*	0.34	0.39	0.53**	0.43*	-0.26			
Zn	-0.31	0.43*	0.37	-0.00	-0.00	-0.01	0.49*	0.41*	0.51*	0.50*	0.14	0.58**	0.41*	0.13		
B	-0.30	0.06	0.05	-0.23	-0.14	-0.22	0.10	0.50*	0.48*	0.21	0.03	0.26	-0.22	-0.22	0.15	
Al	0.21	0.07	0.25	0.05	-0.11	-0.08	-0.07	0.24	-0.03	0.35	0.43*	0.30	-0.48*	0.41*	-0.15	0.11

*, ** indicate significance at 5% and 1% levels, respectively.

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Effects of Watering Depth on the Agronomic Characters, Yield, and Quality of *Euryale ferox* Salisbury[1]

Yuan-Tyab Shyu[2], Sin-Yie Liu[2], Hsiu-Ying Lu[2] and Huey-Ing Liu[3]

Summary

The purpose of this study was to develop a proper watering cultivation method for production and quality improvement of *Euryale ferox* Salisbury through evaluation of four watering depths in the cultivated plastic boxes. Experimental results showed that highly significant or significant effect of different watering depths was recorded on the agronomic characters and yield traits of *Euryale ferox*. Among the four watering depths, plants grown in the 45cm showed a superior performance by its better characteristics, yield and higher content of crude protein and major and minor mineral elements as compared to the other treatments. It was suggested that 45cm might be the most promising watering depth for the future water cultivation of *Euryale ferox*. Correlation analysis showed that except the negative correlation between leaf number and the yield traits such as 100-seed weight the agronomic characters of *Euryale ferox* were highly correlated with its yield traits. That meaned the better development of the petiole could result in stronger growth of leaf, root and seed.

Key words : *Euryale ferox* Salisbury, Watering Depth, Agronomic characters, Yield, Quality.

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有機質肥料之重金屬含量及「肥料規格」之有關規範[1]

連　深　李艷琪[2]

摘要：採集市售及肥料製造業者（包括農業廢棄物處理中心）所生產之有機質肥料共216個，依其材料性質分爲雞糞堆肥、豬糞堆肥、牛糞堆肥、樹皮堆肥、動植物質肥料及雜項有機質肥料，測定各類肥料之銅、鋅、鉻、鎳、鎘、鉛、砷含量，結果如下。雞糞堆肥和豬糞堆肥均含顯著的銅和鋅；雞糞堆肥和豬糞堆肥之銅含量各在9～394及6～301mg/kg範圍，其中超過100mg/kg者達各樣本數之約33及42%；鋅含量各在56～1,147及35～623mg/kg範圍，其中超過500mg/kg者亦達各樣本數之9和5%。現行肥料品目規格中禽畜糞堆肥銅含量之高限爲100mg/kg，可見相當部分的雞糞堆肥和豬糞堆肥均超此高限。鋅含量之高限雖然尚無規定，惟鑒於垃圾堆肥之鋅含量高限已定爲500mg/kg，若干禽畜糞堆肥的高鋅含量仍值注意。豬糞堆肥之鉻含量在3～8,486mg/kg範圍，其中超過150mg/kg者達樣本數之約33%。雜項有機質肥料之鉻含量亦相當顯著，超過150mg/kg者達樣本數之約18%。又豬糞堆肥之鎳含量在4～176mg/kg範圍，超過25mg/kg者佔樣本數之約33%。雜項有機質肥料之鎳含量則在2～92mg/kg範圍，超過25mg/kg者亦達樣本數之22%左右。部份豬糞堆肥和雜項有機質肥料之所以含較高鉻和鎳，係主要與製造過程中皮革粉之摻入有關。現有肥料規格中有關雜項有機質肥料之鉻、鎳含量高限爲：每含1.0鹼度計，鉻不得超過0.1%，鎳不得超過0.01%。由於雜項有機質肥料或豬糞堆肥之鹼度相當高，故其鉻、鎳含量之高限亦必提高；例如鹼度10%者鉻、鎳含量高限應各爲1%及0.1%。故上述肥料中即使鉻含量高達8,000 mg/kg，或鎳含量高達180mg/kg，仍未超過高限。但另一方面，現行肥料規格或肥料國家標準卻規定垃圾堆肥中鉻和鎳各不得高於150及25mg/kg。若依此標準觀之，則上述肥料所含鉻和鎳是否適當，仍值注意。肥料規格中垃圾堆肥之鎘、鉛和砷高限各爲5、150及50 mg/kg。依此標準衡之，除了雜項有機質肥料之極少數外，本調查所涵蓋之有機質肥料之絕大部分均符合規定。

關鍵詞：有機質肥料、重金屬。

據農林廳資料[2]，本省有機質肥料製造業者，截至1993年12月底，已取得肥料登記證者，共有97家，128件。市售之有機質肥料如包括尙未登記者，其數當會更多。由於原料之來源複雜及產製方式之多樣化，有機質肥料在品質上有極大的差異。有機質肥料如原料或加工過程中受到重金屬污染，則肥料中之重金屬偏高，將污染土壤與農產品，繼而影響生態環境與人體健康，值得重視[10]。楊等[7]曾調查11種市售堆肥，結果報告，以豬糞爲材料所製堆肥含銅、鋅和錳的量較高，且有甚大變異；各爲100～1,037，1,533～9,670及633～2,071mg/kg。林等[5]亦曾調查市售肥料樣品56個，惟指出含量較高之重金屬爲鉻、鎳、鋅等三種。Harada et al.[9]亦曾調查日本豬、雞糞堆肥之重金屬含量，指出其銅、鋅含量相當高，係由於飼料中所予者。

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由於有機質肥料之用量大，且爲增進地力，常需長期施用，故其重金屬含量倍受關切。又因原料來源複雜及肥料製造業者衆多，故亟需擴大採樣，調查分析，以便建檔和分類考察，可爲管制有機質肥料品質，防止汚染之依據。

材料與方法

一、肥料樣本之採集及分類：

至全省各地肥料工廠、堆肥處理中心及農業資材行收集或購買不同廠牌有機質肥料（但胺基酸液肥、海藻精等液狀有機質肥料及地方菌、立花菌等微生物性有機肥料除外）；自1991至1993共採集樣品216個（其中部分樣品係在不同年間重複採取）。故本調查所採樣本可大略含蓋全省所有有機質肥料之種類及廠牌。

所採集之有機質肥料，依各肥料之主要原料可分爲(一)動、植物質有機肥料、(二)堆肥和(三)雜項有機質肥料三大類，如表 1 所示。

表1. 採集之有機肥料類別及樣品數
Table 1. Classification of organic manures and the numbers of samples collected

Kinds of manures	No. of Sample	Raw materials
1. 動、植物質有機肥料 Organic manures of animal or vegetable origin	53	
(1)油粕類肥料 Oil cake meal	(28)	大豆粕、棉子粕、菜子粕等 soybean meal, cotton seed meal, vegetable seed meal, etc.
(2)其他植物質有機肥料 Other vegetable organic manures	(13)	花生殼粉、米糠等 peanut husk meal, rice bran, etc.
(3)動物質有機肥料 Organic manures of animal origin	(12)	羊毛粉、骨粉、魚渣、皮革粉等 meals of wool, bone, fish scrap and leather waste, etc.
2. 堆肥 Composts	91	
(1)雞糞堆肥 Poultry waste compost	(35)	雞糞、木屑、穀殼等 poultry feces, saw dust, rice husk, etc
(2)豬糞堆肥 Swine waste compost	(36)	豬糞、木屑、粗糠等 swine feces, saw dust, rice husk, etc
(3)牛糞堆肥 Cattle waste compost	(10)	牛糞、穀殼等 cattle feces, rice husk, etc.
(4)樹皮堆肥 Bark compost	(10)	樹皮 bark
3. 雜項有機質肥料 Miscellaneous organic manures	72	各種動、植物質肥料及堆肥等 mixtures of composts and organic manures of animal or vegetable origin, etc.
合　計 (Total)	216	

(一)動、植物質肥料 (Organic manures of animal or vegetable origin)

此等肥料係屬傳統上最早市販的有機質肥料，可依其原料再分爲；油粕類肥料、其他植物質肥料和動物質肥料，樣本數各爲28、13及12個。油粕類肥料包括棉子粕、蓖麻粕、花生粕和大豆粕等，多數均爲進口者，或爲進口物之加工副產品。其他植物質肥料則包括花生殼、菸莖

、米糠等，均為本地之農場副產物或廢棄物。動物質肥料則包括羊毛粉、皮革粉、骨粉和魚渣等，亦是泰半由外國進口者。此等動物質肥料和植物質肥料亦是日本肥料管理法中唯一稱為「有機質肥料」而以「普通肥料」名義管理者；訂有品目及品目別公定規格（其他有機質肥料則歸為特殊肥料，未訂有品質規格）。此等肥料在農委會公告之「肥料品目及規格表」中亦訂有品目及各品目別特定的保證成分。

此等肥料除了以各原品販賣者外（均歸為動、植物質有機質肥料），亦有很多是用來摻入樹皮、雞糞、豬糞或菇菌類廢包木屑等以製造堆肥者和用來與製好的堆肥混合者；在本調查中前者歸於堆肥，後者則歸為雜項有機質肥料。依照「肥料品目及規格表」之分類或日本肥料管理法之分類，動物質肥料間或植物質肥料間，或動植物肥料間混合所成肥料應稱混合有機質肥料，但因此等肥料亦往往混有雞糞或有關的堆肥，故混合有機肥料與雜項有機質肥料實已難區別，在本調查中為簡便計，不另立混合有機質肥料項目，而均歸於雜項有機質肥料。

(二)堆肥（Compost）

本調查樣本中所歸類之堆肥並不包括農家自製者。其大多數均為業者所產製，以不同廠牌銷售，少部分則為農林廳輔導之大中型堆肥處理中心所產製，亦是對外銷售者。本類堆肥係以禽畜糞等畜產廢棄物與木屑（來自菇菌廢棄包）、穀殼等農產廢棄物混合堆積醱酵所成；亦依材料的主要來源再分為雞糞堆肥、豬糞堆肥、牛糞堆肥和樹皮堆肥，在本調查中所分析之樣本數各有35、36、10和10個。

以菇菌廢包的木屑所堆製的堆肥，在本調查中不另歸為木屑堆肥；因此項木屑一般都用來摻加雞糞或豬糞以堆製堆肥，故歸為雞糞堆肥或豬糞堆肥之類。在「肥料品目及規格表」中，雞糞堆肥、豬糞堆肥和牛糞堆肥係歸為同一品目，禽畜糞堆肥。

(三)雜項有機質肥料（Miscellaneous organic manures）

本調查歸為雜項有機質肥料者，成分最為複雜，係動物質肥料、植物質肥料和堆肥等混合所成（如單純以動物質肥料或植物質肥料混合者，稱為混合有機質肥料，仍歸為動、植物質有機肥料類），其中亦有很多是摻有化學肥料之有機複合肥料，一些不易歸類之有機質肥料亦歸為此類，故廠牌最多，樣本數共有72個。本類肥料與「肥料品目及規格表」中之雜項有機質肥料相當。（禽畜糞堆肥及樹皮堆肥在其堆製過程亦摻有動、植物質肥料，但因原料的比例上係以禽畜糞和樹皮為主，故歸為堆肥，而與雜項有機質肥料有所區別）。

二、肥料成分及重金屬含量之分析：

取1克樣品於磁製坩堝，經灰化後，在水浴上先以5毫升濃硝酸（試藥級）加熱處理，後以25毫升稀鹽酸（試藥級）加熱溶解。過濾後之濾液則以 ICP（感應耦合電漿分光光度計）測定銅、鋅、鎘、鉻、鎳、鉛等含量。砷之定量則取2克樣品於三角瓶，加濃硫酸、濃硝酸和過氯酸（均為試藥級）各2、5和20毫升，置於加熱板上加熱分解，接近乾涸時再追加少量硝酸和過氯酸，繼續加熱至過氯酸的白煙產生並近乾涸止，放冷後加水溶解，過濾之濾液亦以 ICP 測定。

另將標準樣品多種，以同上方法測定各種元素含量，結果測值與標準樣品之標示值符合；顯示本調查所使用之化學分析方法可靠，將以另文報告。

三、樣本各種重金屬含量之累積頻度統計分析：

類似土壤中各種重金屬含量之頻度分布，有機質肥料重金屬含量之頻度分布型亦偏向對數之常態分布（log normal distribution）。以本調查結果資料中豬糞堆肥和雞糞堆肥各36個和35個銅含量為例，以其經過對數變換者和未經過對數變換者各以五分割法[8]比較其頻度分布圖與常態分布之適合性（fitness），顯示兩種堆肥之銅含量頻度分布型均偏向對數之常態分布，如圖1及2。又含量之頻度如改以其累積頻度百分率表示，更易顯示其大於某特定含量之樣本數百分率，一目瞭然。含量

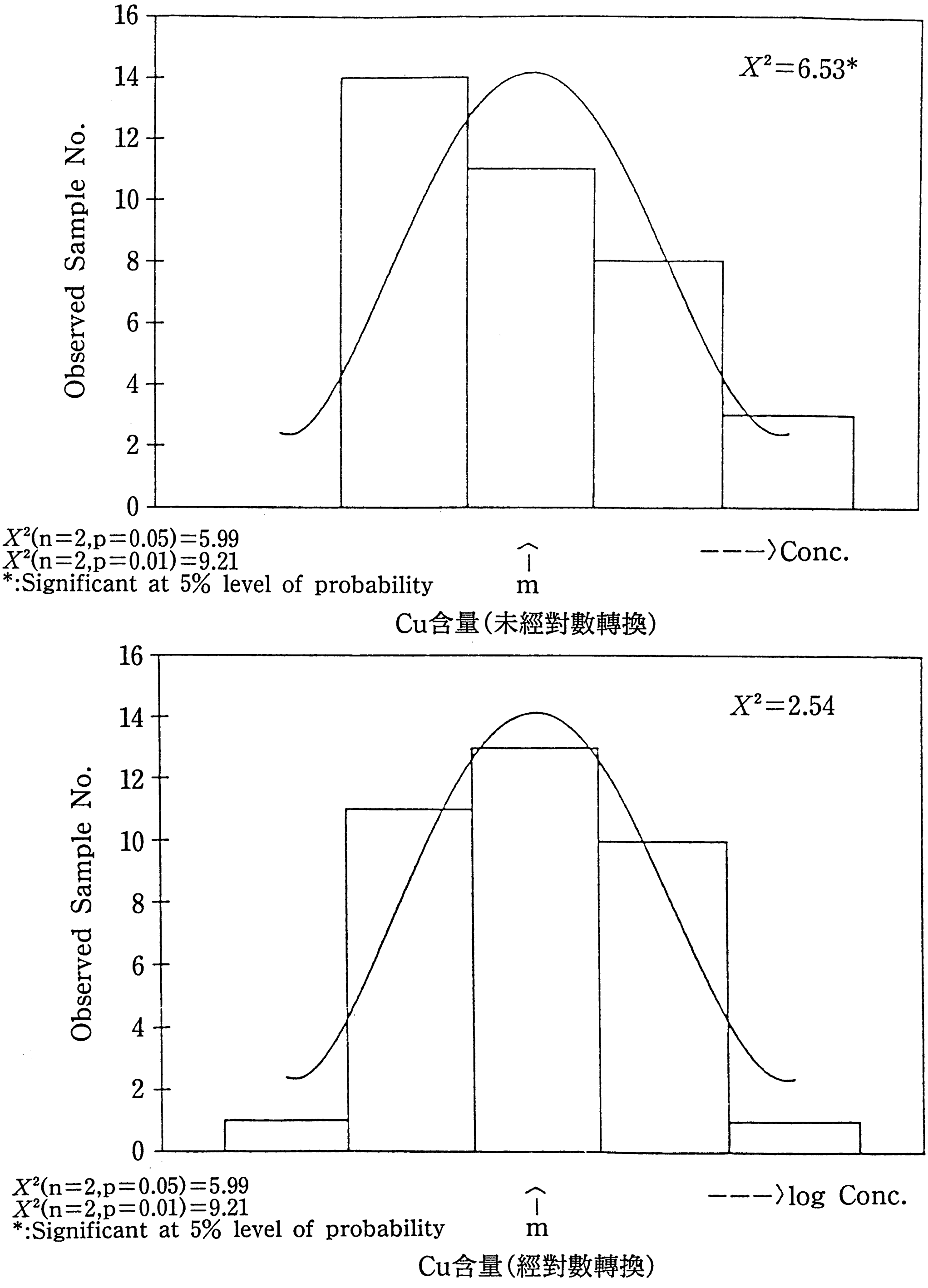

圖1. 豬糞堆肥36個樣品之銅含量經過對數轉換與否之頻度分布型比較

Fig. 1. Comparison of the patterns of frequency distribution of copper concentration untransformed and log-transformed in the 36 swine waste composts

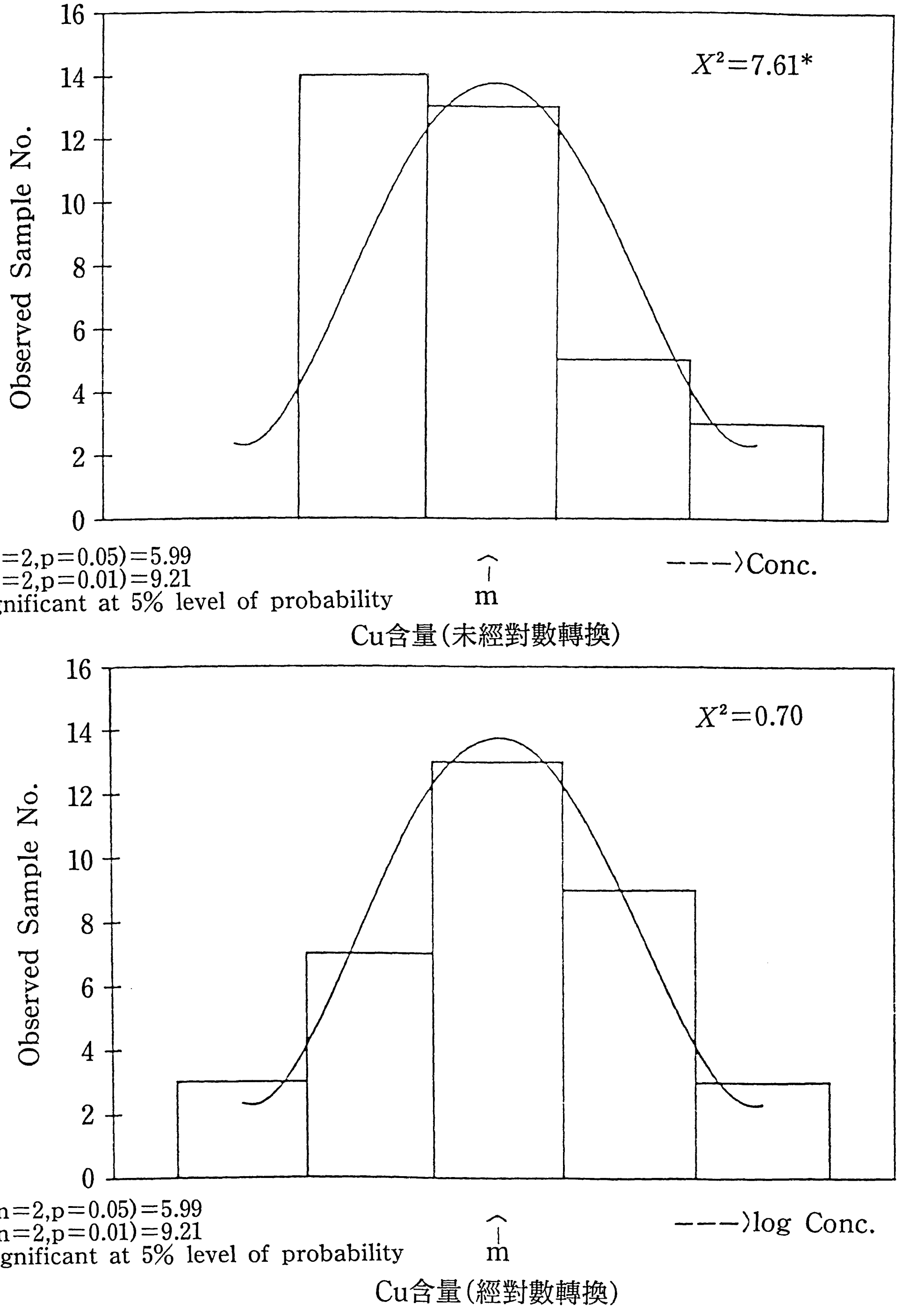

圖2. 雞糞堆肥35個樣品之銅含量經過對數轉換與否之頻度分布型比較

Fig 2. Comparison of the patterns of frequency distribution of copper concentration untransformed and log-transformed in the 35 poultry waste composts

之累積頻度百分率（Xi），亦即含量在某特定值及其以下之樣本數百分率，乃以下式計得：Xi＝（i−0.5）/n×100；i 爲含量由小而大所排之樣本序碼，n 爲樣品總數。此累積頻度百分率如更以常態分布的分位數（Gaussian quantile）尺度標示（累積頻度之常態分布分位數係以累積頻度對應常態分布的分位數表，table of the quantile for the Gaussian distribution, S'teel and Torrie,1980[12] 所查得），則含量的對數與累積頻度對應之常態分布分位數在XY座標上所畫出的點，如成直線，亦可顯示其屬對數常態分布[11]；此時之累積頻度（%）實與常態分布的機率相同。即使所畫出的點不成直線，即其分布型並非對數常態因而不能確定頻度之機率，仍可單純的表示其大於某特定含量之樣本百分率。

由於以上兩種理由，本調查肥料樣本中各種重金屬含量於 X 座標表示時，其尺度（scale）乃用對數值，而含量之頻度爲易於明瞭起見，乃用其累積頻度表示，並以其常態分布的分位數（Gaussian quantile）爲尺度。

四、資料檔（Data basis）之建立：

本調查於不同年度所採及分析之各種有機質肥料，均依一所述分類登錄品牌名稱、採取年度和所測得之氮、磷、鉀、鈣、鎂、有機質和灰分等成分含量（此等成分含量將以另文報告），和銅、鋅、鎘、鉻、鎳、鉛和砷等重金屬含量，並將之輸入電腦，以倚天中文系統和彗星一號文書處理系統建立有機質肥料資料檔。此項資料檔如能繼續擴充，將爲監測有機質肥料品質的重要依據。

結果與討論

各類有機質肥料之重金屬含量變域、中值和各種平均值，如表 2 。爲易於明瞭雞糞堆肥和豬糞堆肥偏高之銅、鋅含量起見，乃將含量之樣品數累積頻度各示於圖 3 及 4 。另亦爲顯示豬糞堆肥和雜項有機質肥料偏高之鉻、鎳含量起見，亦將含量之樣品數累積頻度各示於圖 5 及 6 。

一、銅

雞糞堆肥和豬糞堆肥之銅含量分別在9～394及6～301mg/kg範圍（表 2），其中超過100mg/kg者達各樣品數之約33和42%左右（圖 3）；二者銅含量之累積頻度分布亦甚相似。一般以爲只有豬糞堆肥含有較高的銅，但本調查結果卻顯示雞糞堆肥亦是。Harada et al[9]亦報告日本豬糞堆肥中銅含量高於100mg/kg者佔樣本數之70%，至於雞糞堆肥之銅含量則較低；高於100mg/kg者僅佔樣本數之10%。

李等[4]指出豬隻糞便及糞尿之銅含量隨飼料中銅之添加量增加而增高，且隨餵時間延長，豬隻的糞便的尿中銅的排放量也隨之增高。當添加100、175、250、325mg/kg銅於各處理飼料後，其糞便中銅含量增爲對照組（未添加銅）之 7 、10、16、20倍之多。Harada et al.[9]則指出豬糞中各種重金屬含量均顯著高於豬飼料；豬糞的銅、鋅含量各爲飼料中之4.9～7.6及3.2～4.5倍。可見豬糞堆肥所含銅係來自飼料；預料雞糞堆肥之銅亦是。

雜項有機質肥料之銅含量亦有偏高者；其變域在2～234mg/kg，超過100mg/kg者佔樣本數之10%左右。

無論是豬糞堆肥、雞糞堆肥或雜項有機質肥料，其不同年度所採樣本之銅含量，均尚難看出年度間之任何顯著差異，如表 3 所示。

表2. 各類有機質肥料之重金屬含量（變域、中値、算術平均、幾何平均，單位 mg/kg乾基）

Table 2. Ranges, median and means of heavy metal concentrations in various kinds of organic manures

Kind of manures	No. of Sample	Cu	Zn	Cd	Cr	Ni	Pb	As
1. 動、植物質有機肥料	(Organic manures of animal or vegetable origin)							
(1)油粕類肥料	(28)							
Oil cake meal	range	9-161	37-372	0-2.5	0.2-24	1.4-15	0.3-27	0.7-13
	median	15	47	0	4.3	6.2	2.9	0.87
	mean^z	24	73	0.27	5.7	6.3	4.5	2.6
	mean^y	18	60	0.03	4.1	5.6	2.9	0.43
(2)其他植物質	(13)							
有機肥料	range	1.4-30	10-127	0-0.2	2.1-15	4.0-5.7	0.3-5.1	1.6-100
Other vegetable	median	8.5	43	0	6.3	5.3	4.0	3.6
organic manure	mean^z	15	53	0.03	6.7	4.9	3.0	36
	mean^y	9.3	39	0	5.1	4.8	2.1	10
(3)動物質	(12)							
有機肥料								
Organic manure	range	1.0-561	42-2827	0.-4.8	2-54324	0.7-415	1.4-37	0-66
of animal	median	20	85	0	11	6.0	4.1	2.0
origin	mean^z	84	424	0.68	6,252	47	7.2	9.7
	mean^y	21	144	0.04	37	6.8	4.4	1.1
2. 堆肥 (Composts)								
(1)雞糞堆肥	(35)							
Poultry waste	range	9-394	56-1147	0-6.2	1-282	1.1-30	0-183	0-27.3
compost	median	63	263	1.1	13	12	8.0	7.8
	mean^z	99	286	1.4	23	12	14	9.6
	mean^y	63	245	0.9	13	10	5.4	5.7
(2)豬糞堆肥	(36)							
Swine waste	range	6-301	35-623	0-7.0	3-8486	3.5-176	0.5-60	1.5-113
compost	median	83	232	1.7	29	19	14	14
	mean^z	101	232	1.9	898	32	17	18
	mean^y	77	193	0.7	70	20	13	13
(3)牛糞堆肥	(10)							
Cattle waste	range	14-225	51-308	0-3.7	3.1-314	4.3-18.6	1.6-19	0.3-24
compost	median	46	164	1.22	13	11	6.8	17
	mean^z	82	152	1.36	39	11	7.4	13
	mean^y	56	127	0.42	14	10	5.8	7.3
(4)樹皮堆肥	(10)							
Bark compost	range	22-52	77-216	1.9-5.6	21-46	12-31	13-34	0.9-65
	median	34	115	3.2	27	23	23	21
	mean^z	34	127	3.4	28	23	23	25
	mean^y	33	119	3.2	27	22	22	15
3. 雜項有機質肥料	(72)							
(Miscellaneous	range	2.4-234	5-814	0-5.6	2-9196	2.4-92	0-150	0-57
organic	median	22	108	0.8	25	11	5.9	9.4
manures)	mean^z	38	163	1.2	469	18	11	13
	mean^y	22	111	0.4	41	12	6.1	5.3

^{z} arithmetic mean
^{y} geometric mean

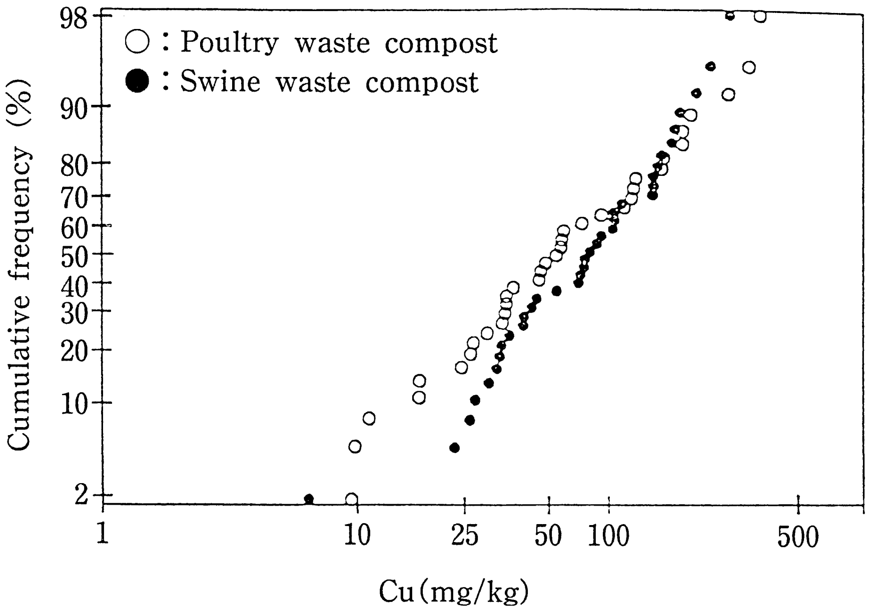

圖3. 雞糞堆肥和豬糞堆肥各35個和36個樣品銅含量之樣品數累積頻度分布

Fig. 3. Cumulative frequency (in quantile scale) of log-transformed concentration of copper in the 35 poultry and 36 swine waste composts

表3. 豬、雞糞堆肥和雜項有機質肥料銅、鋅含量之年度間差異比較

Table 3. Comparison on the concentration differences of copper and zinc between the samples of different years in various organic manures

Kind of manures	year of sampling	No. of sample	Cu mg/kg	Zn mg/kg
豬糞堆肥	80	12	91± 76[z]	190±151
Swine waste compost	81	10	127±53	242± 84
	82	14	156±184	924±203
			F=0.898[y]	F=1.481
雞糞堆肥	80	13	112± 62	340±164
Poultry waste compost	81	11	114±122	266±312
	82	11	108±147	244±104
			F=0.008	F=0.735
雜項有機質肥料	80	15	37±38	155±108
Miscellaneous organic	81	17	41±57	132±103
manure	82	40	38±48	209±216
			F=0.032	F=1.369

[z] mean±standard error

[y] F test ($F_{0.05,2,33}=3.284$; $F_{0.05,2,32}=3.296$; $F_{0.05,2,69}=3.132$)

二、鋅

雞糞堆肥和豬糞堆肥的鋅含量各在56～1,147和35～623mg/kg範圍（表２），其中超過500mg/kg者，達各樣本數之約９和５％（圖４）。Harada et al.[9]所報告之日本雞糞堆肥和豬糞堆肥中鋅含量甚至比本調查所報告者高；超過500mg/kg者達各樣本數之20及50%。因雞和豬的飼料中亦均含相當高的鋅，故雞糞堆肥和豬糞堆肥之鋅含量亦均來自其飼料。雜項有機質肥料之鋅含量亦有偏高者；其變域在5～814mg/kg（表２），超過500mg/kg者亦如豬糞堆肥，佔樣本數之５％左右。

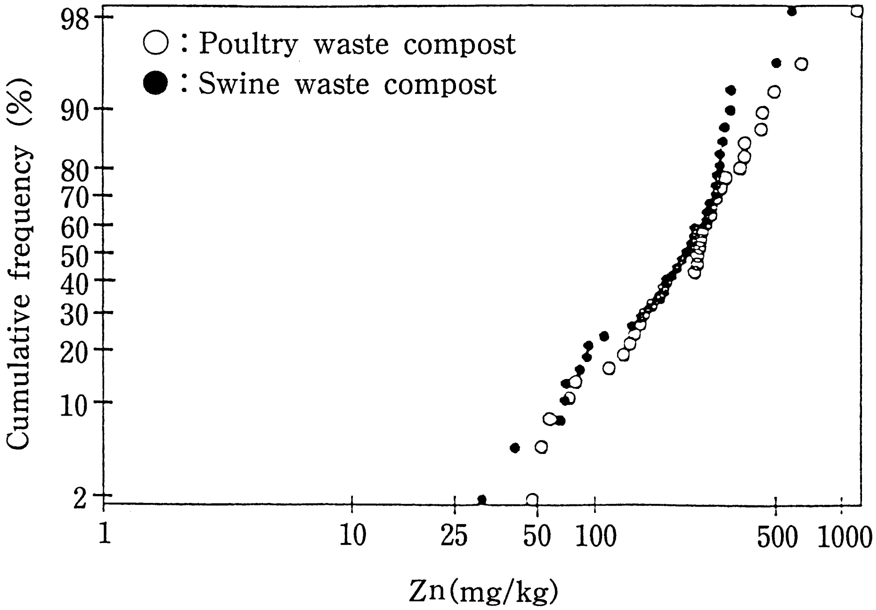

圖4. 雞糞堆肥和豬糞堆肥各35個和36個樣品鋅含量之樣品數累積頻度分布

Fig. 4. Cumulative frequency (in quantile scale) of log-transformed concentration of zinc in the 35 poultry and 36 swine waste composts

無論是豬糞堆肥、雞糞堆肥或雜項有機質肥料，其不同年度所採樣本之鋅含量，均尚難看出年度間之任何顯著差異，如表３所示。

現行肥料品目規格[1,3]中禽畜糞堆肥中銅含量之高限為100mg/kg。鋅含量之高限雖然尚無規定，惟鑒於垃圾堆肥之鋅含量高限已定為500mg/kg，若干堆肥的高鋅含量仍值注意。由於臺灣地區的農作物甚少缺銅和鋅，因而對含銅、鋅有機質肥料之施用，應加以注意，以防污染土壤。

三、鉻、鎳

豬糞堆肥之鉻含量在3～8,486mg/kg範圍；其中超過150mg/kg者達樣本數之約33%。雜項有機質肥料之鉻含量亦相當顯著，在2～9,196mg/kg範圍，超過150mg/kg者達本數之約18%。二者鉻含量之累積頻度分布如圖５所示。

豬糞堆肥之鎳含量在4～176mg/kg範圍，其中超過25mg/kg者達樣本數之約33%。雜項有機質肥料之鎳含量則在2～92mg/kg範圍，超過25mg/kg者亦達樣本數之約22%左右。二者鎳含量之累積頻度分布圖，如圖６。

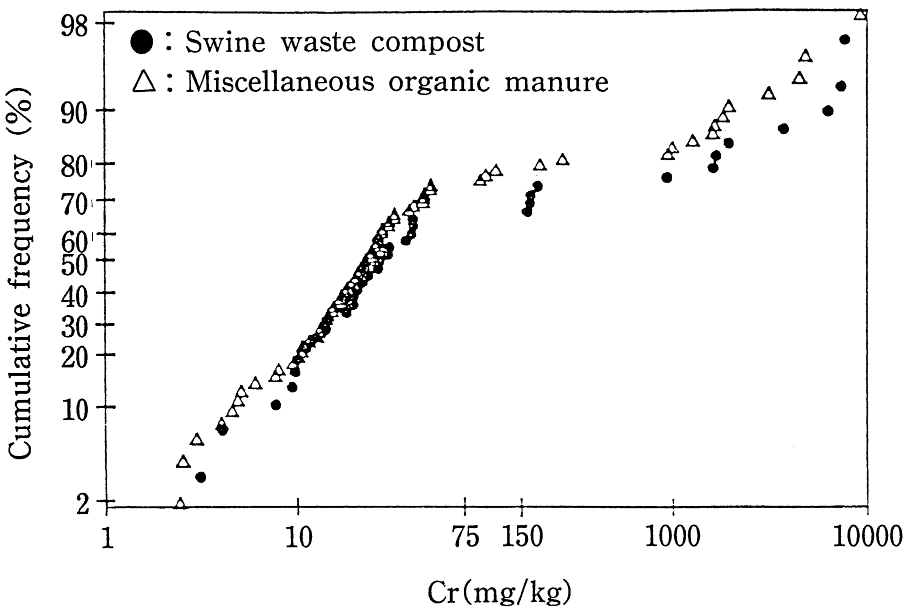

圖5. 豬糞堆肥和雜項堆肥各36個和72個樣品鉻含量之樣品數累積頻度分布

Fig. 5. Cumulative frequency (in quantile scale) of log-transformed concentration of chrome in the 36 swine waste composts and 72 miscellaneous organic manures

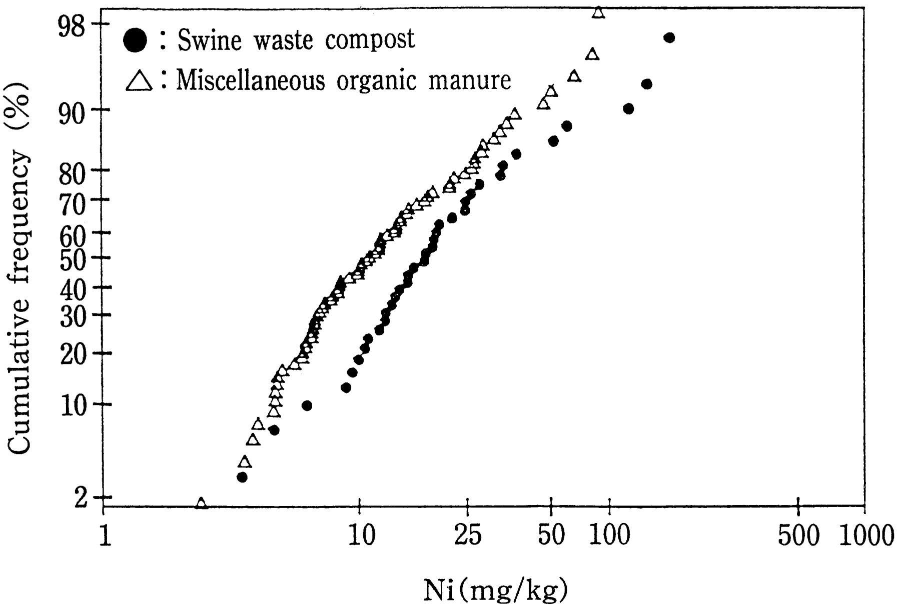

圖6. 豬糞堆肥和雜項堆肥各36個和72個樣品鎳含量之樣品數累積頻度分布

Fig. 6. Cumulative frequency (in quantile scale) of log-transformed concentration of nickel in the 36 swine waste composts and 72 miscellaneous organic manures

單純之豬糞堆肥之鉻和鎳含量應各在數mg/kg以下，可由過去之分析資料了解。雜項有機質肥料如單純以植物質有機肥料和不包括皮革粉之動物質有機肥料所混合者，其鉻和鎳含量亦應不高，可由本調查資料庫中動、植物質有機肥料之鉻、鎳含量範圍窺見一斑。部份豬糞堆肥和雜項堆肥之所以含較高鉻和鎳，係主要與製造過程中皮革粉之摻入有關，可由各種肥料之原料資料了解，亦可由肥料中鉻含量與鎳含量之顯著正相關（表 4 及 5），以及皮革粉中鉻、鎳含量均高（各達5.4%及0.03%）等事實獲得佐證。表2. 動物質有機肥料鉻、鎳含量之範圍之所以很廣（各爲2～54,324及0.4～415 mg/kg）及算術平均值之所以高（各爲6,252及47mg/kg）主要係與該類肥料中之皮革粉有關。

表4. 豬糞堆肥各種重金屬含量間相關係數（n=36）

Table 4. Coefficients of correlations between concentrations of metals in the swine waste composts

Metal	Cu	Zn	Cd	Cr	Ni	Pb	As
Cu	1.000	0.746**	0.010	0.207	0.247	0.176	0.110
Zn		1.000	0.116	0.217	0.302	0.150	0.158
Cd			1.000	0.110	0.079	0.277	0.235
Cr				1.000	0.742**	0.020	0.081
Ni					1.000	0.037	0.070
Pb						1.000	0.191
As							1.000

** Significant at 1 % level of probability

表5. 雜項有機質肥料各種重金屬含量間相關係數（n=72）

Table 5. Coefficients of correlations between concentrations of metals in the miscellaneous organic manures

Metal	Cu	Zn	Cd	Cr	Ni	Pb	As
Cu	1.000	0.613**	0.579**	0.051	0.015	0.063	0.265*
Zn		1.000	0.427**	0.165	0.115	0.477**	0.128
Cd			1.000	0.069	0.152	0.403**	0.518**
Cr				1.000	0.355**	0.105	0.207
Ni					1.000	0.164	0.135
Pb						1.000	0.245*
As							1.000

* Significant at 5 % level of probability
** Significant at 1 % level of probability

現行肥料規格[1,3]中有關雜項有機質肥料之鉻、鎳含量高限爲：每含1.0鹼度計，鉻不得超過0.1%，鎳不得超過0.01%。由於雜項有機質肥料或豬糞堆肥之鹼度相當高，故其鉻、鎳含量之高限亦必提高；例如鹼度10%者鉻、鎳含量高限應各爲 1 %及0.1%。故上述肥料中即使鉻含量高達8000mg/kg，或鎳含量高達180mg/kg，仍未超過高限。日本肥料公定規格[6]中甚至公認蒸製皮革粉爲有機質肥料，對該肥料中之鉻含量亦未見規定。惟鑒於日本肥料公定規格中對於矽酸和石灰礦滓肥料之鉻、鎳含量仍有高限之規定（每含1.0鹼度計，鉻不得超過0.1%，鎳不得超過0.01%，最大限量，鉻4.0%，鎳0.4%。如可溶性矽酸含量未及20%，則最大限量降爲鉻2.0%，鎳0.2%）；我國現行肥料規格或肥料國家標準對於垃圾堆肥中之鉻、鎳含量亦有各不得高於150及25 mg/kg 規定，有機質肥料中含有

如此高量之鉻、鎳是否適當？仍值檢討。

四、鉛、砷

肥料規格中垃圾堆肥之鎘、鉛和砷高限各爲5 、150及50mg/kg。依此標準衡之，本調查所涵蓋之有機質肥料之絕大部分均符合規定，除了部份有機質肥料之極少數外。

誌　謝

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Metal Contents of Organic Manures and the Current Criteria of Regulation[1]

Shen Lian and Yahn-Chir Lee[2]

Summary

Two hundred and sixteen samples of organic manures were collected from either the manufacturers or the sellers during 1990~1993. The manures were classified into (1) composts, i.e., poultry waste compost, swine waste compost and cattle waste compost, and bark compost, (2) organic manures of either animal or vegetable origin, including fish scrap, steamed bone meal, soybean cake meal and rape seed cake meal, etc., and (3) the miscellaneous organic manures which are the miscellaneous mixtures of organic manures. The contents of Cu, Zn, Cr, Ni, Cd, Pb and As in the manures were analyzed and a data base was constructed for quality monitoring. The contents of Cu are generally high in the poultry waste compost and swine waste compost which range 9~394 and 6~301 mg/kg, respectively. A quite good fitness of the frequency distribution to the log normal distribution was observed. The contents of over 100mg/kg were detected in about 33 and 42% of the composts, respectively. The contents of Zn are also high in the poultry waste compost and swine waste compost which range 56~1,147 and 35~623mg/kg, respectively; the contents of over 500mg/kg were detected in about 9 and 5% of the composts, respectively. The contents of Cr are often high in the swine waste compost and the miscellaneous organic manures, which range 2~54,324, 3~8,486 and 2~9,196mg/kg, respectively; the contents of over 150mg/kg were detected in about 33 and 18% of the swine waste compost and the miscellaneous organic manures, respectively. The contents of Ni are also high in the swine waste compost and the miscellaneous organic manures, which range 4~176 and 2~92mg/kg, respectively; the contents of over 25mg/kg were detected in about 33 and 22% of the swine waste compost and miscellaneous organic manures, respectively. The higher contents of Cr and Ni in these manures were conjectured related to the admixing of leather waste which was the byproduct of leather industry using chromium. The metal contents in the above organic manures were also discussed in connection to the current criteria of regulation.

Key words : Organic manures, Heavy metals.

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The Resistance and Cross Resistance of Diamondback Moth, *Plutella xylostella* to *Bacillus thuringiensis* in Taiwan[1]

Ching-Hua Kao and Edward Yun Cheng[2]

Abstract: The *Bacillus thuringiensis* (B.t.) resistance has been examined in diamondback moth (DBM, *Plutella xylostella*), and 4 strains collected from vegetable fields in north(1), central(2) and south(1) of Taiwan were compared to the laboratory-maintained susceptible strain on their sensitivities to six commercial B.t. formulations. Tests were conducted on three fixed dosages i.e., 4,000-, 32,000- and 128,000-fold dilution, from original formulations. In the susceptible strain, three designated dosages caused 96～100%, 58～97% and 41～81% mortalities in contrast to 16～100%, 0～65% and 0～31% mortalities in 4 field strains. The significant lose of B.t. efficacy in the field DBMs has confirmed the existence of B.t. resistance. Thuricide, with its longest marketing history in Taiwan, suffered the worst resistance of R.R.=118.3. The estimated resistance ratios of field DBM to *B.t.* subsp.*kurstaki* are 55.4～118.3. For the single CryIA(c) toxin product, MVP, the resistance ratio is 34.9. Mild cross resistances of *B.t.* subsp. *kurstaki* to *B.t.* subsp. *aizawai* were detected, and the resistance ratios are 9.9～22.0.

By testing the laboratory-reared field DBM colonies on the same 6 designated B.t. formulations, the resistance ratios were 1.3～7.0, and the results indicated their B.t. sensitivities were similar to those of the susceptible strain. Hence the B.t. resistance in DBM will decline when the environment is free from the B.t. selection pressure. Field DBMs collected from different regions showed various insensitivities to all 6 B.t. insecticides, and demonstrated that DBM has responded to the long-term usage of B.t. products in Taiwan's intensively cultured vegetable fields.

Key words: *Plutella xylostella, Bacillus thuringiensis,* Subsp. *aizawai,* Subsp. *kurstaki,* Resistance, Cross resistance

INTRODUCTION

It is hard to define the susceptibility of an organism to its natural pathogens, since all epidemic factors have to be included for consideration. The biological variations of hosts, environmental components for inoculation, and the subsequent disease development, etc., are the possible reasons to restrain researchers from defining the resistance of a pest to its

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microbial pathogens. Although *Bacillus thuringiensis* (B.t.) kills its insect hosts mainly by toxins, the complexity of toxins and combined action of spores still obscured the definition of B.t. resistance. Hence, the B.t. resistance in the diamondback moth (DBM, *Plutella xylostella*) can not be demonstrated earlier until described by Tabashnik *et al.*[5] on a specific crop in a clearly defined culturing environment and a well-documented B.t. application history. B.t. has been widely used in Taiwan for more than 30 years, and mostly served as a supplemental control agent for other chemical insecticides for example, organophosphates and carbamates. On the other hand, there has not a native B.t. susceptible DBM strain been maintained in Taiwan, which hampered the investigation of B.t. resistance in DBM because the study should best base on a native susceptible strain to distinguish the induced resistance from the natural tolerance. Investigation into the B.t. resistance in DBM was started from establishing a native B.t.-susceptible DBM strain, and the IL-strain that has been maintained in Taiwan Agricultural Research Institute (TARI) for more than 130 generations was compared to the Abbott Laboratories' susceptible DBM (AL-strain) in a parallel study.

MATERIALS AND METHODS

Insecticides

Six commercial B.t. formulations were used in this study. They were mostly developed and marketed recently except Thuricide. B.t. formulations were diluted with distilled water containing 333 ppm Triton X-100 to 4,000-, 32,000- and 128,000-fold for bioassay. The B.t. formulations tested were:

1. Javelin, 6.4% WG (*B.t.* subsp. *kurstaki,* 32000IU/mg, Sandoz)
2. Thuricide HP, 3% SP (*B.t.* subsp. *kurstaki,* 16000IU/mg, Sandoz)
3. Dipel 2X, 6.4% WP (*B.t.* subsp. *kurstaki,* 32000IU/mg, Abbott Lab.)
4. Xentari, 10.3% WDG (*B.t.* subsp. *aizawai,* Abbott Lab.)
5. MVP, 10% AF (CryIA(C), Mycogen Corp.)
6. Turex, 3.8% WP (B.t. *aizawai,* transconjugated from *B.t.* subsp. *kurstaki,* and *B.t.* supsp. *aizawai,* Ciba Geigy)

Commercialized chemical insecticides were used for testing the susceptibilities of IL- and AL-strain of DBM, and the formulations used were:

1. Fenvaletate, 20% EC
2. Permethrin, 10% EC
3. Cypermethrin, 5% EC
4. Mevinphos, 25.3% EC
5. Profenofos, 43% EC
6. Quinalphos, 25% EC
7. Methidathion, 40% EC
8. Methamidophos, 50% EC
9. Pirimiphos-methyl, 26.3% EC
10. Phenthoate, 50% EC
11. Carbofuran, 40.64% FP
12. Methomyl, 90% WP

Insect materials:

1. Susceptible strains:
   IL-strain (native of Taiwan, Pesticide Res. Lab., TARI)
   AL-strain (Abbott laboratories, USA)
2. Field resistant strains: collected in June-August, 1993.

FR1: collected from San-chung in northern Taiwan.

FR2: collected from Hsi-hu in central Taiwan.

FR3: collected from Hsi-lo in central Taiwan.

FR4: collected from Lu-chuin in southern Taiwan.

3. Laboratory maintained field colonies: field strains resistant to chemical insecticides that have been reared in laboratory free from insecticide selection since 1989.

L1 colony

L2 colony

L3 colony

Spray tower method:

Sensitivities of the susceptible IL-and AL-strain DBM to chemical insecticides were compared by using the Potter Spray Tower method. Commercial insecticides were diluted with distilled water into serial dilutions within the range of LC_{10} and LC_{90}, and 1 ml of test solution was sprayed on both sides of the leaf disc (ca. 7×7 cm^2). Each dosage was tested on total of 45—60 late 3rd instar larvae in three replicates[1]. Mortalities were recorded at 24 hr after treatment and the results were analyzed in probit[2].

Bioassay method :

Leaf dipping method was used for testing the susceptibilities of DBM to B.t. Leaf discs with a diameter of 3.5 cm were cut from cabbage leaves which had been washed and air-dried. Twenty-four leaf discs for 4 replicates were prepared for each dosage and dipped for 5 seconds in B.t. solutions containing 333 ppm Triton X-100 and then left to air-dry. For the control test, cabbage leaf discs were dipped in distilled water with 333 ppm Triton X-100 only and then were air-dried on wire racks.

Four treated leaf discs and 15 late 3rd instar DBM larvae were put in a petri dish as one replicate in the beginning, and at 48 hr interval, the other two treated leaf discs been kept at 5°C were added for further observation. Total of 60 DBM larvae in 4 replicates were subjected to all treatments, and the mortalities were assessed at 72 hr after the start of treatment. Analyses were made by correcting with the control first, and then analyzed by probit[2]. If the DBM mortality in the control lot was over 8%, the test was abandoned and repeated.

RESULTS

To select a proper susceptible strain for the study, both chemical and B.t. sensitivities of IL-strain and AL-strain were examined. Although IL-strain is highly sensitive when compared to field collected DBMs[1], it is more resistant than the AL-strain with respect to chemical insecticides (Table 1).

The B.t. susceptibilities of IL-strain to 6 commercial formulations in three dilutions were compared to the AL-strain (Table 2). For MVP and Turex, slightly lower LC_{50}s were obtained for the IL-strain than the AL-strain, while similar LC_{50} values were obtained in Dipel and Xentari, and only Javelin and Thuricide concluded higher LC_{50} values in the IL-strain than the AL-strain. In analysis, all the LC_{50} differences between two strains in respect of any B.t. formulation were not significant at 95% fiducial limit (F.L.).

Table 1. Comparison of sensitivities of AL-strain and the native susceptible IL-strain to three major chemical insecticide groups

Insecticides	LC_{50}, mg/liter	
	IL-strain	AL-strain
Synthetic pyrethroids		
Fenvalerate	8.3	3.1
Permethrin	14.0	8.1
Cypermethrin	19.0	1.6
Organophosphates		
Mevinphos	73.0	10.5
Profenofos	100.0	44.4
Quinalphos	230.0	5.5
Methidathion	270.0	11.9
Methamidophos	560.0	57.9
Pirimiphos-methyl		17.9
Phenthoate	670.0	44.4
Carbamates		
Carbofuran	120.0	20.7
Methomyl	3,400.0	21.1

Table 2. Sensitivities of two susceptible DBM strains to six commercial B.t. products

B. t.	IL-strain		AL-strains	
products	LC_{50}^{z} (Slope)	95% F. L.	LC_{50}^{z} (Slope)	95% F. L.
Javelin	2.3(1.61)	0.4～ 4.3	0.4(1.16)	0～ 2.1
Thuricide	13.0(1.18)	6.7～20.4	4.9(2.18)	1.6～ 7.4
Dipel 2X	2.9(1.73)	0.2～ 5.6	2.9(1.04)	0.3～ 6.6
Xentari	15.1(1.30)	8.5～23.3	10.4(1.36)	5.5～15.9
MVP	6.2(1.73)	2.6～ 9.3	10.6(0.52)	0.7～26.9
Turex	2.7(1.10)	0.3～ 6.0	9.9(1.45)	5.4～14.9

[z] Concentration: mg/liter

Comparative study was conducted by testing the susceptibilities of four field-collected DBM strains to six B.t. products at 4,000-, 32,000- and 128,000-fold dilutions, and the results were present in Table 3. In respect of the effect of dosage on different strains, the lowest dosage at 128,000-fold dilution of 6 tested B.t. products caused 41～81% mortalities in the susceptible strain, while 0～9% mortalities were observed in FR1-strain, 7～31% in FR2-strain, 0～17% in FR3-strain, and 0～12% in FR4-strain. The medium dosage, or the 32,000-fold dilution, caused 58～97% mortalities in IL-strain, compared to 3～30% in FR1-strain, 23～65% in FR2-strain, 0～21% in FR3-strain, and 0～23% in FR4-strain. The highest dosage, the 4,000-fold dilution, caused 96～100% mortalities in the susceptible strain in contrast to only 29～97%, 44～94%, 20～100% and 16～75% mortalities in the FR1-, FR2-, FR3- and FR4-strains, respectively.

The DBMs collected in Taiwan's intensively cultured vegetable fields had demonstrated 55- to 118-fold resistance to 3 commercial B.t. products derived from *B.t.* subsp. *kurstaki,* and the strongest resistance is for Thuricide with the longest marketed history in Taiwan (Table 4). Same field DBMs showed a medium degree of resistance to the single toxin product, MVP, while two newer B.t. products of *B.t.* subsp. *aizawai,* Xentari and Turex, also suffered 10- to 20-fold resistance, or 10—40% of the resistance for *B.t.* subsp. *kurstaki.*

TARI has maintained 3 colonies of field DBM in laboratory for more than 50 generations without any B.t. selection. These strains were also tested against the same 6 B.t. formulations at the same discriminating dosages (Table 3), and the resistance ratios ranged from 1.3 to 7.0 (Table 4), which were not significantly different from the susceptible DBM. Instead, all their 95% F.L. of LC_{50} were distinct from those of freshly collected field DBMs.

Table 3. Comparing the susceptibilities of the susceptible, laboratory-reared, and field strains to 6 B.t. products at 3 disriminating dosages

B.t. products	Dilutions[z]	Mortality (%)								
		Susceptible		Lab.-reared			Field			
		IL	AL	L1	L2	L3	FR1	FR2	FR3	FR4
Javelin	4000X	100	100	100	100	87	47	86	46	75
	32000X	97	99	94	64	87	17	44	10	15
	128000X	81	94	80	52	49	3	28	0	6
Thuricide	4000X	96	100	100	100	88	35	44	20	16
	32000X	60	97	86	76	26	10	27	8	0
	128000X	45	67	40	22	9	8	13	0	0
Dipel 2X	4000X	100	98	100	96	80	54	69	58	60
	32000X	97	85	75	53	41	15	25	17	13
	128000X	77	68	63	39	18	0	10	17	12
Xentari	4000X	97	98	100	98	91	68	88	59	27
	32000X	58	71	83	49	33	22	23	16	23
	128000X	41	46	51	43	5	9	7	6	0
MVP	4000X	100	73	100	100	77	29	94	55	36
	32000X	89	69	58	91	11	3	65	0	7
	128000X	58	42	44	57	9	2	31	0	6
Turex	4000X	100	100	100	100	98	97	86	100	60
	32000X	84	70	73	71	30	30	43	21	22
	128000X	73	49	24	52	15	7	19	3	5

[z] Equivalent dosages:
4000X = 250.0mg/liter
32000X = 31.3mg/liter
128000X = 7.8mg/liter

Table 4. The sensitivities and resistance ratios (R. R.) of the L- and FR-strains compared to IL-strain

B.t. porducts	Lab-strains(3)			FR-strains(4)		
	LC_{50}[z] (Slope)	95%F. L	R.R.[y]	LC_{50}[z] (Slope)	95%F. L	R.R.[y]
Javelin	4.2(0.99)	1.6～ 7.3	1.8	132.3(1.15)	93.5～ 207.3	57.5
Thuricide	21.1(1.66)	16.4～26.7	1.6	1,538.0(0.71)	531.7～17,812.4	118.3
Dipel 2X	16.6(1.09)	10.9～23.2	5.7	160.8(1.10)	110.4～ 267.9	55.4
Xentari	19.6(1.42)	12.6～28.6	1.3	150.1(1.23)	107.2～ 232.1	9.9
MVP	19.3(1.16)	11.1～30.0	3.1	216.4(0.96)	136.7～ 430.5	34.9
Turex	18.9(1.71)	13.1～26.3	7.0	59.6(1.66)	47.0～ 77.0	22.0

[z] Concentration: mg/liter.
[y] Resistance ratios (R. R). were calculated in respect of IL-strain.

DISCUSSION

Tabashnik[5] had judged from the mode of action study of B.T. that the resistance should result only from B.t. selection rather than from the cross resistance of other chemical insecticides. This point of view had been demonstrated and validated since both AL- and IL-strains have the same sensitivities to B.t., while their LC_{50}s to various chemical insecticides are different. The IL-strain was therefore chosen for the subsequent comparisons because it is a native strain of Taiwan, and genetically is more comparable to those field collected DBMs than the AL-strain.

Among different B.t. products, Thuricide, with its long history of usage, was not effective even in the highest testing concentration. Better performance at the highest concentration was observed for the newer B.t. products e.g., Javelin, Dipel 2X, Xentari and Turex, while MVP was effective only in the FR2-strain. The results also demonstrated that the B.t. resistance is strain-dependent e.g., the DBM collected from Hsi-hu (FR3-strain) was more susceptible to B.t. than the DBMs from other regions. This might be caused by the local variation of B.t. used as hypothesized by Tabashnik[5]. The laboratory test results showed the average effectiveness of products in field DBM followed the order of Turex, Javelin, Xentari, Dipel 2X, MVP and Thuricide.

Since all 4 field strains were collected before any *B.t.* subsp. *aizawai* product was marketed, the possibility of a mild cross resistance from *B.t.* subsp. *kurstaki* to *B.t.* subsp. *aizawai* is obvious. The cross resistance between different isolates of *B.t.* subsp. *kurstaki* in DBM had been documented by Tabashnik *et al.*[5] and Shelton *et al.*[4], and also by McGaughey and Johnson[3] in *Plodia interpunctella*. Mild cross resistance of *B.t.* subsp. *kurstaki* to *B.t.* subsp. *aizawai* in DBM had been detected by Shelton *et al.*[4] and Tabashnik *et al.*[6], but the Taiwan field DBM showed stronger cross resistance between these two B.t . subspecies.

Due to the discovery of resistance and cross resistance of B.t., serious consideration should be given on the selection of different B.t. formulations for DBM control in respect of resistance management. Whether *B.t.* subsp. *kurstaki* and *B.t.* subsp. *aizawai* can be alternated should also be tested and discussed since different subspecies still have over-

lapped portions in toxin compositions. In cautious, we suggest the B.t. should be alternated with insecticides with chemical nature, or with a mode of action deviated from B.t., for example, the newly registered abamectin.

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小菜蛾對蘇力菌抗藥性及交互抗性[1]

高靜華 鄭 允[2]

摘 要

由三重、溪湖、西螺及路竹採得之小菜蛾以六種商品化之蘇力菌配方（Thuricide、Dipel 2X、Javelin、MVP、Xentari 及 Turex）測試其感度，並與室內之感性品系進行比較，發現所測試的三個稀釋濃度（4,000倍、32,000倍及128,000倍）下，感性品系之死亡率分別爲爲96～100%、58～97%及41～81%。而田間品系在相同的三個濃度下，死亡率則爲16～100%、0～65%及0～31%，顯示蘇力菌對田間小菜蛾之防治效率已經降低，而證實蘇力菌之抗藥性確實已經發生，尤其以在本省使用歷史最長之 Thuricide 之抗性最高，其抗性比爲118.3。經估計，所採得之田間小菜蛾對三種 *kurstaki* 亞種之蘇力菌商品，Javelin、Dipel 2X 及 Thuricide，之抗性比爲55.4～118.3，對蘇力菌單一毒素之產品 MVP 抗性比爲34.9。試驗中並檢測出 *B.t.* subsp. *kurstaki* 造成兩種 *B.t. subsp. aizawai* 產品 Xentari 及 Turex 之交互抗性，其抗性比爲9.9～22.0。以採自相同地區，在室內飼養四年且未受蘇力菌汰選之田間品系測試，對蘇力菌之感度僅微次於感性品系，抗性比在1.3～7.0之間，與田間新採集之小菜蛾對蘇力菌感度有顯著之差異，顯示歷經一段無汰選時期後，小菜蛾對蘇力菌之敏感度會逐漸恢復。本研究確認本省小菜蛾已普遍對兩個蘇力菌亞種之商品均產生抗藥性，且其原因應來自田間長期使用蘇力菌所致。

關鍵詞：小菜蛾、蘇力菌、抗藥性、交互抗性、kurstaki 品系、aizawai 品系。

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農試型落花生聯合收穫機油壓動力系統液壓油冷卻效果之探討分析[1]

梁連勝　陸龍虎　顏秀榮[2]

摘要：農試型落花生聯合收穫機油動力系統中液壓油之冷卻效率，受到動力系統組件摩擦損失及洩壓閥洩壓損失之影響；其中尤以洩壓所導致之熱損失爲最，佔系統所產生全部熱量之50%以上。因此要降低油壓系統之作業油溫，最直接之途徑爲使用經濟合理之油壓組件如泵、馬達等。同時，若油壓系統以空氣爲熱交換介質時，其冷卻效率亦可經由選擇最佳冷卻面積與通過冷卻器氣流速度予以提高。

關鍵詞：收穫機、油壓、冷卻效率。

在自然界任何運動中之物體因互動關係均會因摩擦而生熱，油壓機械之系統元件因液壓油流動摩擦所生之熱，大部份均由液壓油吸收而導致油溫上升，當液壓油之溫度升高後，其黏度亦相對降低；但液壓油之黏度爲決定其品質與系統元件致動效率之主要因素，其變化幅度決定了油壓元件與系統之整體作業性能。由於農試II型落花生聯合收穫機之動力系統完全以油壓取代傳統之機械式結構，因此在應用上亦遭遇到系統溫度異常升高之問題，如何克服其系統溫度不致超過正常作業之安全範圍爲亟待解決之課題。在本型收穫機油壓動力系統之規劃、設計時，除了必須達到作業之要求外，機械空間之使用與元件之成本爲必須先行考慮者；否則，所規劃之系統或因價昂而增加收穫之整體成本，或因無法配合實際作業環境而不適用。最明顯之限制爲冷卻方式之選擇，因田間作業環境限制，必需使用冷卻率較低之空氣，導致系統使用油量必需適度增加，這一選擇衍生了本系統冷卻效率低與液壓油溫度偏高等問題。於整體油壓系統中，致動油溫度之升高來自油壓裝置系統內部所生之熱量，此熱量可概分爲泵及馬達之動力損失、經由釋壓閥洩油及管路組件抵抗損失所產生之熱量等三部份，該三項熱源可經由理論式或以經驗式予以評估探討[1,2,3]。

材料與方法

農試II型落花生聯合收穫機之油壓動力分別供應作業與行駛二系統致動所需之高壓油，在作業系統中又分爲四個支系統（圖1），其作業功能分別爲舉升、拔取、脫莢及選別等，每一支系統中各單一作業液壓馬達係以串聯之方式組合使用。前處理夾持系統之額定作業轉速爲124RPM，系統每分鐘需油量爲9.98公升；脫莢筒之額定作業轉速爲450RPM，系統每分鐘需高壓油23.96公升；選別系統中柵鏈之額定作業轉速爲77RPM，每分鐘需油14.98公升；總計作業系統在正常作業情況下，泵浦每分鐘需供應70kg/cm^{2}之高壓油48.92公升。當收穫機以每秒鐘0.43公尺之速度進行收穫作業時，行駛系統之馬達需由泵浦供應50kg/cm^{2}之高壓油40公升，作業與行駛兩動力系統比例閥之洩油壓力預設

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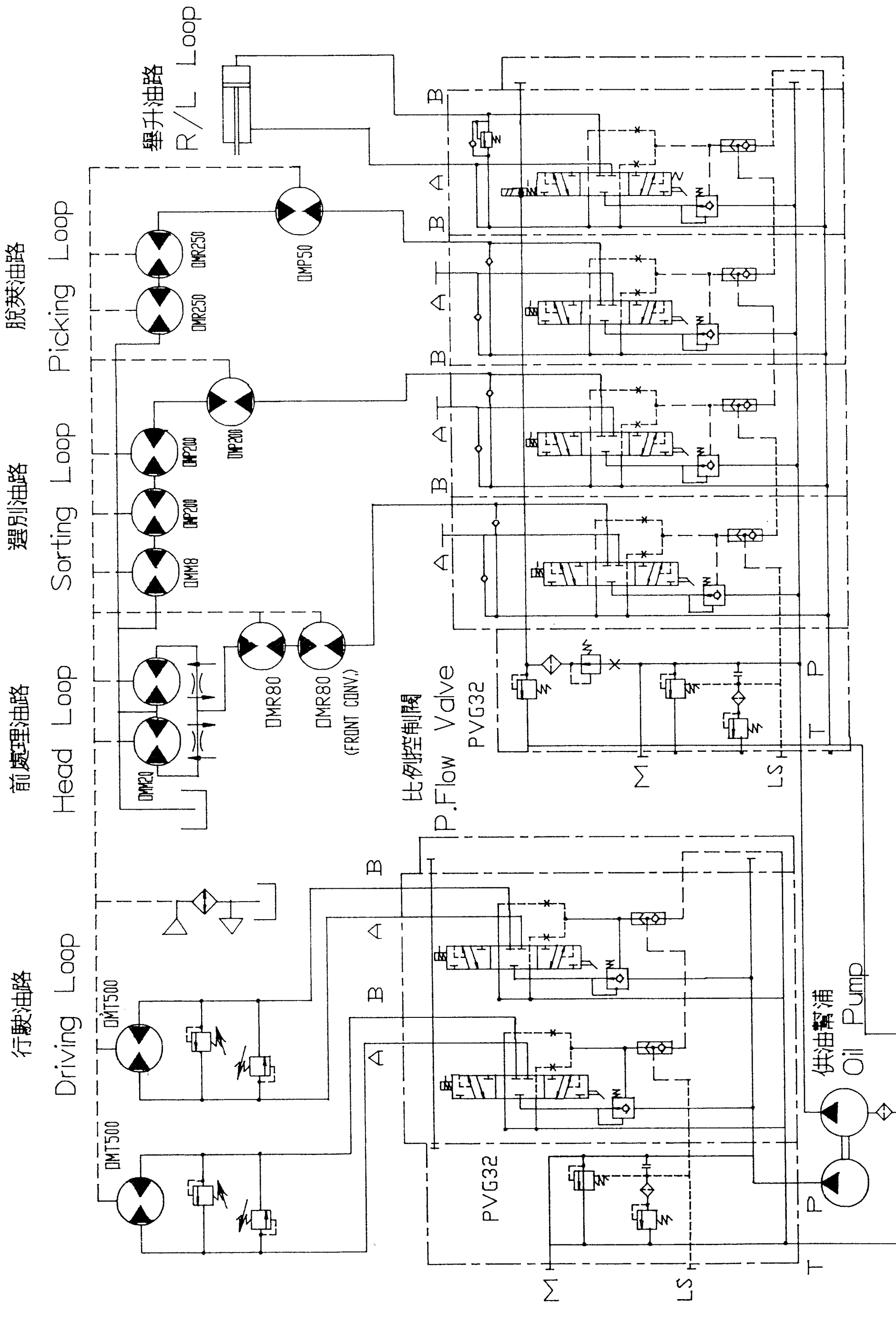

圖1. 油壓動力系統回路

Fig. 1. The Loop of the Hydraulic Power System

爲150kg/cm2及100kg/cm^2；當收穫機在田間持續作業且系統油溫達到穩定後，以風速計及紅外線測溫器沿冷卻器之對角線與其中點位置，檢測並紀錄冷卻器吸入與排出口之氣流速度與溫度，求出平均風速與平均溫度；並應用精密溫度感測器檢測冷卻器出、入口之即時油溫，以供進行系統熱收支之探討分析。

結果與討論

本液壓系統冷卻器之熱交換介質爲空氣，在一般落花生之收穫季節，農田之大氣溫度通常介於30～40°C，因此在本冷卻效率分析中，有關空氣之定容比熱與密度兩物理性質[4]分別定爲0.17Kcal/kg°C及1.2929公斤/立方公尺（表1）。系統所使用液壓油之比熱及密度爲0.45Kcal/kg°C及0.85公斤／公升。於整體油壓系統中，總泵軸之動力 W、泵及馬達之動力損失所產生之熱（H_1）、經由釋壓閥產生之熱（H_2）及管路抵抗損失所產生之熱（H_3）等，分別以下列四式計算之[3]。

$W=(P\times Q)\div(612\times\eta)$ (Kw) ……(1)

$H_1=860\times W\times(1-\eta)$ Kcal/Hr ……(2)

$H_2=600\times Pr\times Qr\div 427$Kcal/Hr ……(3)

$H_3=860\times W\times K$ Kcal/Hr ……(4)

表1. 空氣之比熱

Table 1. Zero pressure specific heats for air in B/1b-F

Temp.	Air		
F	Cp	Cv	K
32	0.240	0.171	1.401
100	0.240	0.172	1.400
200	0.241	0.173	1.397
300	0.243	0.174	1.394
500	0.248	0.179	1.383
750	0.255	0.187	1.368
1,000	0.263	0.194	1.353
1,500	0.276	0.208	1.330
2,000	0.286	0.217	1.316
3,000	0.297	0.229	1.300
4,000	0.305	0.236	1.291

上式中 W 爲泵軸所需動力、P 爲泵吐出壓力（kg/cm^2）、Q爲各壓力下之吐出量（L/Min）、η爲泵之全效率，假設以0.83計算之、W 爲泵軸之入力（Kw）、Pr 爲釋壓閥之設定壓力(kg/cm^2)、Qr 爲通過釋壓閥之油量、K 爲介於0.10～0.15之常數。各系統之熱收支，利用上述四式分析如后。

當收穫機在田間正常作業時，大氣溫度爲33°C；在作業溫度達穩定平衡狀態時，經實測冷卻器吸入口與排出口空氣之溫度分別爲33°C及42°C，氣流通過39公分×46公分、四排鰭管冷卻器之平均流速爲每秒5.4公尺，冷卻風扇之截面積爲0.159平方公尺，則每小時通過冷卻器之空氣量應爲3,685公斤。作業中引擎係以每分鐘2,250轉之額定轉速運轉，作業與行駛系統雙聯供油泵，採用每轉33.9cc及26.2cc之排量，則每分鐘之供油量（Q）分別爲76.28公升與58.95公升；對該二泵而言，其所供應之高壓油與系統所需之理論驅動需油量相較，溢供系統之餘油爲27.36與18.95公升，該溢供之高壓油應爲本系統液壓油溫度升高之主要熱源。爲計算系統之熱收支，首先必需計算系統之動力授受，由式（1）

系統泵浦軸之動力需求 W（Kw）分別爲 W_1及 W_2。

W_1＝（70×76.28）÷（612×0.83）＝10.5（Kw）……(5)

W_2＝（50×58.95）÷（612×0.83）＝5.8（Kw）……(6)

系統之摩擦熱如下：

H_1＝860（10.5＋5.8）×（1－0.83）＝2,383 Kcal/Hr ……(7)

H_2＝600×（150×27.36＋100×18.95）÷427＝8,430 Kcal/Hr ……(8)

H_3＝860×（10.5＋5.8）×0.15＝2,103 Kcal/Hr……(9)

合併第（7）、（8）及（9）式，則系統所產生之熱量爲215Kcal/Hr。當系統連續運轉作業 1 小時後，系統之液壓油溫度逐漸升高，至約 1 小時30分後油溫趨於平衡穩定狀態；此時系統所發生之熱量除一部份作爲保持平衡油溫之熱源外，其餘之熱量理論上應被冷卻器之空氣除去。由於在油溫達到平衡時，經實測冷卻器出、入口油溫分別爲82.2°C及80°C。則系統液壓油經冷卻器後，每分鐘耗用之熱量（H_0）爲：

H_0＝0.45×0.85×（76.28＋58.95）×（82.2－80）＝114Kcal/Min ……(10)

但空氣流經冷卻器時，每分鐘應除去之熱量（Ha）爲：

Ha＝5.4×60×0.159×0.172×1.2929×（42.9－33）＝113Kcal/Min……(11)

（10）與（11）式比較結果，冷卻器除去熱量爲113Kcal/Min小於液壓油失去熱量1Kcal/Min，該誤差應爲冷卻器表面所散失之熱量，故系統溫度應可保持穩定；至於系統總發熱量減去冷卻油溫所失去之熱量後，每分鐘殘餘101Kcal/Min，爲保持油箱中液壓平衡油溫及管路散熱所需之熱量。

唯本動力系統模式之作業溫高達80°C，已超過一般建議之安全範圍；根據熱收支平衡分析，系統洩壓所造成之熱源佔總熱量之65.3%，系統動力損失引起者佔18.4%，其餘16.3%係由管路抵抗所引起；因此，若要降低系統油溫，則可在引擎額定負載輸出作業轉速下，選擇最經濟之泵，供應最適量之高壓油，爲首要考慮之重點，藉此可能減少超量供應高壓油後洩壓所導致之熱量；或者提高冷卻器之冷卻效率，以獲致降低油溫之效果。

由上述分析，爲了降低液壓油之作業溫度上限，可經由改變泵之輸出規格或提高冷卻效率兩方法來達成，首先以改變冷卻效率之方式加以分析。在原動力系統回路中，將冷卻器加大爲54公分×62公分，裝置五排鰭管，通過冷卻器之氣流速度平均爲每秒5.35公尺，扇葉之直徑爲50公分，油箱之液壓油量爲334公升。當系統在氣溫30°C下連續運轉 2 小時後，測得平衡穩定狀態時卻器出、入口油溫分別爲54.3°C及52°C，經實測得知冷卻器吸入與排出口空氣之平均溫度分別爲30及39°C。

在進行本修正分析時，引擎以2,400RPM運轉，因此泵之輸出分別爲81.36公升與62.88公升，如前述計算可得：

W_1＝（70×81.36）÷（612×0.83）＝11.2（Kw）……(12)

W_2＝（50×62.88）÷（612×0.83）＝6.2（Kw）……(13)

H_1＝860（11.2＋6.2）×（1－0.83）＝254Kcal/Hr ……(14)

H_2＝600×（150×32.44＋100×22.88）÷427＝1,005Kcal/Hr ……(15)

H_3＝860×（11.2＋6.2）×0.15＝2,245Kcal/Hr……(16)

合併第（15）、（16）及（17）式，則系統所產生之熱量（H）爲247Kcal/Min。當系統連續運轉作業 2 小時後，系統之液壓油溫度趨於平衡穩定狀態；此時系統所發生之熱量除一部份作爲保持平衡油溫之熱源外，其餘之熱量理論上應被冷卻器之空氣除去。由於在油溫達到平衡時，經實測冷卻器出、入口油溫分別爲54.3°C及52°C。則系統液壓油經冷卻器後，每分鐘耗用之熱量（H_0）爲：

H_0＝0.45×0.85×（81.36＋62.88）×（54.3－52）＝127Kcal/Min ……(17)

但空氣流經冷卻器時，每分鐘應除去之熱量（Ha）爲：

$Ha=5.35\times60\times0.196\times0.172\times1.2929\times(39-30)=126Kcal/Min$ ……………………(18)

(17) 與 (18) 式比較結果，冷卻器除去熱量爲126Kcal/Min，小於液壓油失去熱量1Kcal/Min，該誤差應爲冷卻器表面所散失之熱量，故系統溫度應可保持穩定；至於系統總發熱量減去冷卻油溫所失去之熱量後，每分鐘殘餘120Kcal/Min，爲保持油箱中液壓油平衡油溫及管路散熱所需之熱量。

爲減少洩油所導致之大部份熱源，本系統供油泵浦之排量若修正爲25.4cc/Rev，當引擎以每分鐘2,500轉作業時，兩組泵之額定排量均修正爲每分鐘63.5公升，而作業與行駛系統每分鐘所需之額定工作油量分別爲48.9及40公升，故二作業系統泵超供液壓油分別爲14.6與23.5公升。冷卻風扇之截面積仍爲0.159㎡，風扇出風口之平均風速爲每秒5.2公尺，油箱中儲存380公升之液壓油。依據 (1)、(2)、(3) 及 (4) 式，分別計算泵軸所需之動力、泵及馬達之動力損失所產生之熱 (H_1)、由釋壓閥產生之熱 (H_2) 及系統管路抵抗所產生之熱 (H_3) 如下：

$W_1=(70\times63.5)\div(612\times0.83)=8.75(Kw)$ ……………………………………………(19)

$W_2=(50\times63.5)\div(612\times0.83)=6.25(Kw)$ ……………………………………………(20)

$H_1=860(8.75+6.25)\times(1-0.83)=2,193Kcal/Hr$ ……………………………………(21)

$H_2=600\times(150\times14.6+100\times23.5)\div427=6,379Kcal/Hr$ ……………………………(22)

$H_3=860\times(8.75+6.25)\times0.1Kcal/Hr=1,935Kcal/Hr$ ……………………………………(23)

合併第 (21)、(22) 及 (23) 式，則系統所產生之熱量 (H) 爲247Kcal/Min。當系統連續運轉作業2小時後，系統之液壓油溫度趨於平衡穩定狀態；此時系統所發生之熱量除一部份作爲保持平衡油溫之熱源外，其餘之熱量理論上應被冷卻器之空氣除去。由於在油溫達到平衡時，經實測冷卻器出、入口油溫分別爲57.3°C及55°C，經實測得知冷卻器吸入與排出口空氣之平均溫度分別爲33及42.9°C。則系統液壓油經冷卻器後，每分鐘耗用之熱量 (H_0) 爲：

$H_0=0.45\times0.85\times(63.5+63.5)\times(57.3-55)=111Kcal/Min$ ………………………(24)

$Ha=5.2\times60\times0.196\times0.172\times1.2929\times(42.9-33)=109Kcal/Min$ ……………………(25)

(24) 與 (25) 式比較結果，冷卻器除去熱量爲109Kcal/Min，小於液壓油失去熱量2Kcal/Min，該誤差應爲冷卻器表面所散失之熱量，故系統溫度應可保持穩定；至於系統總發熱量減去冷卻油溫所失去之熱量後，每分鐘殘餘64Kcal/Min，爲保持油箱中液壓油平衡油溫及管路散熱所需之熱量。

由前述三個系統模式之熱分析可知，油壓系統之冷卻器若以空氣爲熱交換介質時，爲提高冷卻效率，可藉選擇最適宜之冷卻氣流流速與熱交換面積或使用更合理之泵輸出量，以減少洩油所產生之大量熱源，上述結果可由使用者依據實際作業需求作適當之選擇與組合，以達到冷卻效率高且經濟之油壓動力系統模式。

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Analysis on the Fluid Cooling Effect for the TARI Peanut Harvester Hydraulic Power Driving System[1]

Lien-Sheng Liang, Long-Hu Lu and Shiu-Rong Yen[2]

Summary

The heat induces by the releasing of the hydraulic power system caused by the friction between its elements and oil is the major influencing parameter on cooling. It contributes more than 50% of heat hence affects the system cooling efficiency more than 50% among the parameters. There is a better way to reduce the system temperature by using a reasonably sized pump. If the air been used as the heat exchange medium, the cooling efficiency can be increased by properly enlarging the cooling surface and air speed.

Key words : Harvester, Hydraulic, Cooling Efficiency.

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A Study on the Vibration of an Elastic Sphere[1]

Li-Duhng Huarng[2] and Pictiaw Chen[3]

Abstract : A theoretical analysis of the vibration of an elastic sphere in spherical coordinates using the scalar and vector potential equations by the separation of variables method leads to the solutions of the trigonmetric equation, the Legendre equation and the Bessel equation. The associated Legendre polynomials of the first kind govern the mode shapes of vibration while the spherical Bessel functions of the first kind lead to the non-dimensional frequencies of the vibration modes The simplest vibration modes of a homogeneous elastic sphere are the pure compressional modes and the pure shear modes. The procedures to solve the non-dimensional frequencies for some cases of both the pure compressional modes and the pure shear modes are illustrated in the contents. Although, the solutions for the cases of the mixed modes of vibration are too complicated to be solved analytically, a different approach method published by Lamb in 1882 are included. A table for the non-dimensional frequencies of the mixed class vibration obtained numerically with a computer program for Poisson's ratio; ν; equals to 0.1, 0.2, 0.3 and 0.4, given by Cooke and Rand are also included for quick reference.

Key words : Vibration mode, Non-dimensional frequency, Elastic Sphere.

INTRODUCTION

The vibration of a solid elastic sphere is an old problem. The radibal oscillation of a sphere was studied as early as 1828 by S. D. Poisson (16). The problem related to the elastic sphere was then continually developed by Lamb (1882) and other scienists. Lamb's work has the advantage of discussing the simpler modes of vibration of a uniform sphere in detsils with the method of obtaining roots of the frequency equations. He classified the general types of vibration into the "first class" and the "second class" (3,7,11,16). The first class referred to the torsional class vibration modes which result in a dilation-free (no volume change) motion. The second class referred to the spheroidal vibration modes where the displacements have radial components and the volume may change.

The Navier equation which governs the dynamic responses of a linear, elastic, homogeneous, isotropic sphere can be dissloved into three equations, namely, the trigonometric

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equation, the Legendre equation and the Bessel equation(7,17)). Among the solutions to these equations, the Bessel functions of the first kind are used to obtain the non-dimensional frequencies which can be applied to predict the second and the third resonant frequencies of an intact apple from the first resonant frequencies while the Legendre polynomials are associated with the vibration modes[2,3,8].

MATERIALS AND METHODS

1. Theoretical model:

The Navier equation which governs the small motion of an isotropic elastic sphere without any body forces can be expressed as follows[1,2,13,14]:

$$\mu\nabla^2\bar{u}+(\lambda+\mu)\nabla[\nabla\cdot\bar{u}]=\rho\ddot{\bar{u}} \quad \cdots\cdots (1)$$

where:

λ, μ = Lame's constant

$\bar{u}$ = displacement vector

ρ = mass density

∇^2 = Laplacian operator

∇ = gradient operator

The solutions of equation (1) could be obtained if the displacement vector $\bar{u}$ is represented in terms of a scalar potential ϕ and a vector potential $\bar{\Psi}$[1,2,7,8]:

$$\bar{u}=\nabla\phi+\nabla\Psi \quad \cdots\cdots (2)$$

Substituting equation (2) into equation (1), results in:

$$\mu\nabla^2(\nabla\phi+\nabla\times\bar{\Psi})+(\lambda+\mu)\nabla[\nabla\cdot(\nabla\phi+\nabla\times\bar{\Psi})]=\rho\frac{\partial^2[\nabla\phi+\nabla\times\bar{\Psi}]}{\partial t^2} \quad \cdots\cdots (3)$$

But $\nabla\cdot\nabla\times\bar{\Psi}=0$

and $\nabla\cdot\nabla\phi=\nabla^2\phi \quad \cdots\cdots (4)$

Therefore, equation 3 becomes

$$\nabla[(\lambda+2\mu)\nabla^2\phi-\rho\ddot{\phi}]+\nabla\times(\mu\nabla^2\bar{\Psi}-\rho\ddot{\bar{\Psi}})=0 \quad \cdots\cdots (5)$$

The displacement equation 2 will satisfy the Navier equation, if

$$\nabla^2\phi=\frac{1}{V_l^2}\ddot{\phi} \quad \text{where} \quad V_l=\left(\frac{\lambda+2\mu}{\rho}\right)^{\frac{1}{2}} \quad \cdots\cdots (6)$$

and

$$\nabla^2\bar{\Psi}=\frac{1}{V_s^2}\bar{\Psi} \quad \text{where} \quad V_s=\left(\frac{\mu}{\rho}\right)^{\frac{1}{2}} \quad \cdots\cdots (7)$$

V_l and V_s are called the compressional (or longitudinal) phase velocity and shear (or flexural) phase velocity[3], respectively.

The vector wave equation 7 is satisfied if the following scalar wave function is satisfied [14]:

$$\nabla^2\Psi+\frac{\omega^2}{V_s^2}\Psi=0 \quad \cdots\cdots (8)$$

Equations 6 and 8 are similar and can be solved by the separation of variables method [2,14,17]. The detailed procedures for determining these solutins in a spherical coordinate system can be found in Huarng (1992). The following is a description of the procedure for determining the solution ϕ of the scalar wave equation 6.

If we define ϕ as a product of a displacement function and a time function as follows:

$$\phi=\Phi(r,\ \theta,\ \delta)\ T(t) \quad \cdots\cdots (9)$$

where r, $\theta$and δ are spherical coordinates as shown in Fig. 1, and t is time.

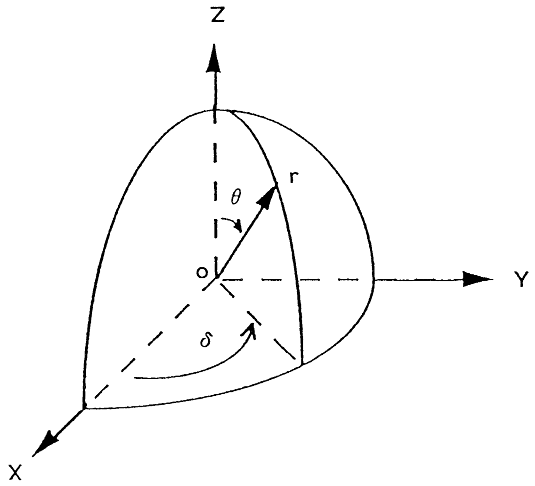

Fig. 1. Spherical coordinate for a sphere

Substituting eqtation 9 into equation 6 results in:

$$V_l^2\frac{\nabla^2\Phi}{\Phi}=\frac{\ddot{T}}{T} \quad \cdots\cdots (10)$$

Since the left hand side of equation 10 is a function of spatial variables only, and that on the right hand side is a function of time only, both sides must be equal to a constant. Therefore, we can write:

$$V_l^2\frac{\nabla^2\Phi}{\Phi}=\frac{\ddot{T}}{T}=-\omega^2 \quad \cdots\cdots (11)$$

Equation 11 yields

$$\ddot{T}+\omega^2T=0 \quad \cdots\cdots (12)$$

and

$$\nabla^2\Phi+\frac{\omega 2}{V_l^2}\Phi=0 \quad \cdots\cdots (13)$$

The solutions for equation 12 is of the form $T=e^{-i\omega t}$. Equaation 13 in spherical coordinates can be expressed as[7,9]:

$$\frac{1}{r^2}\left[\frac{\partial}{\partial r}\left(r^2\frac{\partial\Phi}{\partial r}\right)+\frac{1}{\sin\theta}\ \frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial\Phi}{\partial\theta}\right)+\frac{1}{\sin^2\theta}\ \frac{\partial^2\Phi}{\partial\delta^2}\right]+\frac{\omega^2}{V_l^2}\Phi=0 \quad \cdots\cdots (14)$$

Equation 14 is separable; thus by letting Φ $(r, \theta, \delta) = R(r)\Theta(\theta)\triangle(\delta)$, one can separate equation 14 into the following three differential equations[7,17]:

$$\frac{d^2\triangle}{d\delta^2}+m^2\triangle=0 \qquad (15)$$

$$\frac{d^2\Theta}{d\theta^2}+\frac{\cos\theta}{\sin\theta}\frac{d\Theta}{d\theta}+\left(k^2-\frac{m^2}{\sin^2\theta}\right)\Theta=0 \qquad (16)$$

$$\frac{d^2R}{dr^2}+\frac{2}{r}\frac{dR}{dr}+\left(\frac{\omega^2}{V_l^2}-\frac{k^2}{r^2}\right)R=0 \qquad (17)$$

where m^2 and k^2 are the separation constant.

The general solution of equation 15 is:

$$\triangle(\delta)=e^{-1m\delta} \qquad (18)$$

To obtain a single valued potential function with the range of δ to be $(0,2\pi)$, m must be an interer [4](i. e., $m=0,\pm1,\pm2,\pm3,\cdots\cdots$).

It can be shown that physically meaningful solutions of equation 16 exists only when $k^2=n\ (n+1)$, $n=0, 1, 2, 3,\cdots$, etc.[14,17]. For these values of k^2, the solutions of equation 16 are the associated Legendre polynomials of the first kind as represented below:

$$\Theta(\theta)=P_n^{|m|}(\cos\theta)$$

$$=(1-\cos^2\theta)^{\frac{|m|}{2}}\frac{d^{|m|}}{d\cos\theta^{|m|}}P_n(\cos\theta) \qquad (19)$$

where $n=0, 1, 2,\cdots\cdots$; and P_n $(\cos\theta)$ is the Legendre polynomial which can be expressed in Rodrigues' formula form as[2,4,6,14]:

$$P_n(\cos\theta)=\frac{1}{2^n n\,!}\frac{d^n}{d(\cos\theta)^n}(\cos^2\theta-1)^n \qquad (20)$$

Since P_n $(\cos\theta)$ is a polynomial of nth degree, $\Theta(\theta)$ vanishes when $m>n$. Therefore, the values of $|m|$ in equation 19 is limited to $|m|\leqq n$.

The solutions of equation 17 are the spherical Bessel functions of the first kind represented as:

$$R(r)=\sqrt{\frac{2}{\pi}\left(\frac{\omega}{V_l}\right)}\,Z_n\left(\frac{\omega r}{V_l}\right) \qquad (21)$$

where

$$Z_n(\rho)=\sqrt{\frac{\pi}{2\rho}}\,Z_{n+1/2}(\rho) \qquad (22)$$

and $Z_{n+1/2}$ (ρ) is the Bessel function of the first kind of order $n+1/2$.

Thereforefore, the solutions to equation 13 are:

$$\Phi_{mn}(r, \theta,\delta)=Z_n\left(\frac{\omega r}{V_l}\right)P_n^{|m|}(\cos\theta)\,e^{im\delta} \qquad (23)$$

where $n=0, 1, 2, 3,\cdots\cdots$and $|m|=1, 2, \cdots\cdots,n$.

Combining the solutions of equations 12 and 13, one obtains the solutions of equation 6 as:

$$\phi_{nm}=Z_n\left(\frac{\omega r}{V_l}\right)P_n^{|m|}(\cos\theta)e^{lm\delta}e^{-1\omega t} \qquad (24)$$

It was shown by Pao and Mow (1973) that the vector wave equation

$$\nabla^2\bar{\Psi}+\frac{\omega^2}{V_s^2}\bar{\Psi}=0 \qquad (25)$$

is satisfied if the following scalar wave function is satisfied. i. e.

$$\nabla^2\Psi+\frac{\omega^2}{V_s^2}\Psi=0 \qquad (26)$$

The above scalar wave function can be solved in the same manner as used for the scalar function in equation (13). The result leads to the solutions of the form[2,7]

$$\Psi_{mn}(r,\ \theta,\ \delta)=Z_n\left(\frac{\omega r}{V_s}\right) P_n^{|m|}\ (\cos\theta)e^{im\delta} \qquad (27)$$

2. Vibration modes:

The torsional class vibration can be expressed as $T_{n\ell-1}$ and the spheroidal class vibration as $S_{n\ell-1}$[2], where n is a non-negative integer and $\ell=1, 2, 3,\cdots$ is the order of roots satisfying the frequency equations.

The simplest vibration modes of a homogeneous elastic sphere are pure compressional modes and pure shear modes. For the pure compressional modes, the procedure for obtaining the non-dimensional frequencies are illustated below:

2.1 Pure Compressional Modes

For a solid sppherical resonator, the spherical Bessel functions of the first kind can be applied. And the scalar potential would be

$$\Phi_{mn}(r,\ \theta,\ \delta)=Z_n\left(\frac{\omega r}{V_\ell}\right) P_n^{|m|}(\cos\theta)\ e^{im\delta} \qquad (23)$$

If m=n=0, from equation 2, these solutions simplify to

$$\begin{aligned}\bar{u}_{mn}&=\bar{u}_{00}\\ &=\nabla\Phi_{00}\ (r,\ \theta,\ \delta)\\ &=\nabla z_0\left(\frac{\omega r}{V_\ell}\right)\\ &=\hat{r}\ \frac{d}{dr}\ z_0\left(\frac{\omega r}{V_\ell}\right)\end{aligned} \qquad (28)$$

Where $\hat{r}$ is the unit position vector.

And the strain field associated with equation (28) has only 3 components[28]. Namely,

$$S_{rr}=\frac{1}{i\omega}\ \frac{\partial u_r}{\partial r}$$

$$S_{\theta\theta}=\frac{1}{i\omega}\ \frac{u_r}{r}$$

$$S_{\delta\delta}=\frac{1}{i\omega}\frac{u_r}{r} \qquad (29)$$

where $i=\sqrt{-1}$.

Therefore, the traction force on the spherical surface is [2]

$$\begin{aligned}T.\ \hat{r}&=T_{rr}\\ &=c_{11}\ S_{rr}+c_{12}\ (S_{\theta\theta}+S_{\delta\delta})\end{aligned} \qquad (30)$$

So, the stress-free boundary condition on the spherical surface (r=a) is

$$c_{11}\frac{d^2}{dr^2}Z_0\left(\frac{\omega r}{V_l}\right)+\frac{2c_{12}}{r}\frac{d}{dr}Z_0\left(\frac{\omega r}{V_l}\right)=0 \qquad (31)$$

Since $Z_0(\rho)=\sin\rho/\rho$[2,7,18], we know that

$$Z_0\left(\frac{\omega r}{V_l}\right)=\frac{\sin\left(\frac{\omega r}{V_l}\right)}{\left(\frac{\omega r}{V_l}\right)} \qquad (32)$$

The definition of Poison's ratio, ν, in terms of the stiffness constants, c_{jn}, where j and n are integers, is as follows[2,7]:

$$\nu=\frac{c_{11}-2c_{44}}{2(c_{11}-c_{44})} \qquad (33)$$

Therefore, the ratio of c_{11} to c_{44} can be found as:

$$\frac{c_{11}}{c_{44}}=\frac{2-2\nu}{1-2\nu} \qquad (34)$$

and since $c_{12}=c_{11}-2c_{44}$ for isotropic materials[2,7], substitution of equation (32) into equation (31) at r=a yields the characteristic frequency equation:

$$\tan\left(\frac{\omega a}{V_l}\right)=\frac{\left(\frac{\omega a}{V_l}\right)}{1-\frac{c_{11}}{4c_{44}}\left(\frac{\omega a}{V_l}\right)^2}=\frac{\left(\frac{\omega a}{V_l}\right)}{1-\left(\frac{1-\nu}{2-4\nu}\right)\left(\frac{\omega a}{V_l}\right)^2} \qquad (35)$$

If the roots of equation (35) are designated as s_{00l}, where the first two subscripts indicate m =n=0 in equation (23), the natural frequencies of these family of modes are

$$f=\frac{V_l}{2\pi a}s_{00l} \qquad (36)$$

Where these modes are conventionally labeled S_{0l}.

Now, for the case of v=0.3, which is commonly used as Poisson's ratio for apples[3], equation (35) becomes

$$\tan\left(\frac{\omega a}{V_l}\right)=\frac{\left(\frac{\omega a}{V_l}\right)}{1-\left(\frac{7}{8}\right)\left(\frac{\omega a}{V_l}\right)^2} \qquad (37)$$

The solutions to equation (37) are the non-dimensional frequencies, $\frac{\omega a}{V_l}$, designated as H (=ha). The first four roots (excluding the trivial solution, 0) of this equation are

$$H=ha=\frac{\omega a}{V_l}=2.6702,\ 6.0920,\ 9.3009,\ 12.4743 \qquad (38)$$

which correspond to the S_{01}, S_{02}, S_{03} and S_{04} modes, respectively.

2.2 Pure shear modes

The particle motion under pure shear modes is always normal to the radial coordinate, and

$$u_\theta=\frac{1}{\sin\theta}\frac{\partial\Psi_{mn}}{\partial\delta} \qquad (39)$$

$$u_\delta=-\frac{\partial\Psi_{mn}}{\partial\theta} \qquad (40)$$

Because the field must remain finite at r=0, the spherical Bessel function of the first kind was considered in equation (27).

The strain field corresponding to equations (39) and (40) has 5 components, $S_{\theta\theta}$, $S_{\delta\delta}$, $S_{r\theta}$, $S_{r\delta}$ and $S_{\theta\delta}$[2,7]. Also the spherical surface traction force is

$$T.\hat{r}=\hat{\theta}\frac{c_{44}}{i\omega}\left(\frac{\partial u_\theta}{\partial r}\ \frac{\partial u_\theta}{\partial r}-\frac{u_\theta}{r}\right)+\hat{\delta}\frac{c_{44}}{i\omega}\left(\frac{\partial u_\delta}{\partial r}-\frac{u_\delta}{r}\right) \quad \cdots\cdots(41)$$

where $\hat{\theta}$ and $\hat{\delta}$ are the spherical unit vector.

Substituting equations (39) and (40) into stress-free boundary condition $T.\hat{r}=0$ at $r=a$ yields characteristic equation in the variable $\left(\frac{\omega a}{Vs}\right)$. Shear modes are conventionally designated as $T_{n\ell-1}$, where ℓ is the order of roots satisfying the frequency equation. For the case where m=0 and n=1, the particle velocity field is

$$\bar{u}_{01}=\hat{\delta}\frac{\partial}{\partial\theta}\Psi_{01}=-\hat{\delta}\cos\theta\, Z_1\left(\frac{\omega r}{V_s}\right) \quad \cdots\cdots(42)$$

and the frequency relation reduces to

$$\tan\left(\frac{\omega a}{V_s}\right)=\frac{\left(\frac{\omega a}{V_s}\right)}{1-\frac{1}{3}\left(\frac{\omega a}{V_s}\right)^2} \quad \cdots\cdots(43)$$

The solutions to equation (43) are the non-dimensional frequencies $\frac{\omega a}{V_s}$, designated as H (=ka). The first four roots (excluding the trivial solution, 0) of this equation are

$$H=ka=\frac{\omega a}{V_s}=5.7635,\ 9.0950,\ 12.3229,\ 15.5146 \quad \cdots\cdots(44)$$

which correspond to the T_{11}, T_{12}, T_{13} and T_{14} modes, respectively.

2.3 Mixed Modes

Imposition of the stress free boundary conditions at the sphere surface (r=a) to solve a combination of spherical shear wave equations and compressional equations leads to a complicated frequency relation, which must be solved numerically[2,15]. The modes associated with the complicated frequency relation are usually designated as $S_{n\ell-1}$.

The following is a different approach which was first published by Lamb in 1882. Before investigating these vibration frequencies, the $\Psi_n(\theta)$ function used in the mixed mode frequency equations is defined as[18].

$$\Psi_n(\theta)=\frac{\Gamma\left(n+\frac{3}{2}\right)}{\left(\frac{1}{2}\theta\right)^{n+\frac{1}{2}}}Z_{n+\frac{1}{2}}(\theta)$$

$$=1-\frac{\theta^2}{2\cdot(2n+3)}+\frac{\theta_4}{2\cdot 4\cdot(2n+3)\cdot(2n+5)}-\text{etc}\cdots\cdots$$

$$=(-1)^n\cdot 1\cdot 3\cdot 5\cdots(2n+1)\cdot\left(\frac{d}{\theta\, d\theta}\right)^n\frac{\sin\theta}{\theta} \quad \cdots\cdots(45)$$

where $Z_{n+\frac{1}{2}}(\theta)$ is the Bessel equation and the Gamma function $\Gamma(\alpha)$ is defined as[9]:

$$\Gamma(\alpha)=\int_0^\infty e^{-t}\, t^{\alpha-1}\, dt \qquad (\alpha>0) \quad \cdots\cdots(46)$$

with the following properties:

$$\Gamma(\alpha+1)=\alpha\Gamma(\alpha) \quad \cdots\cdots (47)$$

and

$$\Gamma\left(\frac{1}{2}\right)=\sqrt{\pi} \quad \cdots\cdots (48)$$

The function $\Psi_n(\theta)$ has the following properties[10,11]:

$$\Psi_n'(\theta)=-\frac{\theta}{2n+3}\Psi_{n+1}(\theta) \quad \cdots\cdots (49)$$

$$\Psi_n(\theta)-\Psi_{n-1}(\theta)=\frac{\theta^2}{(2n+1)(2n+3)}\Psi_{n+1}(\theta) \quad \cdots\cdots (50)$$

which is useful in solving frequency equations and checking the values of the $\Psi_n(\theta)$. The first five $\Psi_n(\theta)$ function values are:

$$\Psi_1(\theta)=(-1)^1\cdot 1\cdot 3\cdot\left(\frac{d}{\theta\, d\theta}\right)^1\frac{\sin\theta}{\theta}$$

$$=-3\left(\frac{1}{\theta}\right)\frac{d}{d\theta}\left(\frac{\sin\theta}{\theta}\right)$$

$$=\frac{-3\theta\cos\theta+3\sin\theta}{\theta^3} \quad \cdots\cdots (51)$$

$$\Psi_2(\theta)=(-1)^2\cdot 1\cdot 3\cdot 5\cdot\left(\frac{d}{\theta\, d\theta}\right)^2\frac{\sin\theta}{\theta}$$

$$=15\left(\frac{1}{\theta}\frac{d}{d\theta}\right)\left(\frac{1}{\theta}\frac{d}{d\theta}\left(\frac{\sin\theta}{\theta}\right)\right)$$

$$=15\left(\frac{1}{\theta}\frac{d}{d\theta}\right)\left(\frac{1}{\theta}\left(\frac{\theta\cos\theta-\sin\theta}{\theta^2}\right)\right)$$

$$=15\left(\frac{1}{\theta}\frac{d}{d\theta}\right)\left(\left(\frac{\theta\cos\theta-\sin\theta}{\theta^3}\right)\right)$$

$$=15\left(\frac{1}{\theta}\ \frac{3\ \theta\sin\theta-3\theta\cos\theta-\theta^2\sin\theta}{\theta^4}\right)$$

$$=\frac{-15\theta^2\sin\theta-45\theta\cos\theta+45\sin\theta}{\theta^5} \quad \cdots\cdots (52)$$

$$\Psi_3(\theta)=(-1)^3\cdot 1\cdot 3\cdot 5\cdot 7\cdot\left(\frac{d}{\theta\, d\theta}\right)^3\frac{\sin\theta}{\theta}$$

$$=-105\left(\frac{d}{\theta\, d\theta}\right)\left(\frac{d}{\theta\, d\theta}\right)\left(\frac{d}{\theta\, d\theta}\right)\frac{\sin\theta}{\theta}$$

$$=\frac{105\theta^3\cos\theta-630\theta^2\sin\theta-1575\theta\cos\theta+1575\sin\theta}{\theta^7} \quad \cdots\cdots (53)$$

$$\Psi_4(\theta)=(-1)^4\cdot 1\cdot 3\cdot 5\cdot 7\cdot 9\cdot\left(\frac{d}{\theta\, d\theta}\right)^4\frac{\sin\theta}{\theta}$$

$$=945\left(\frac{d}{\theta\, d\theta}\right)\left(\frac{d}{\theta\, d\theta}\right)\left(\frac{d}{\theta\, d\theta}\right)\left(\frac{d}{\theta\, d\theta}\right)\frac{\sin\theta}{\theta}$$

$$=\frac{1}{\theta^9}(945\theta^4\sin\theta+9450\theta^3\cos\theta-42525\theta^2\sin\theta-99225\theta\cos\theta+99225\sin\theta) \quad \cdots\cdots (54)$$

$$\Psi_5(\theta)=(-1)^5\cdot 1\cdot 3\cdot 5\cdot 7\cdot 9\cdot 11\cdot\left(\frac{d}{\theta\, d\theta}\right)^5\frac{\sin\theta}{\theta}$$

$$=-10395\left(\frac{d}{\theta\, d\theta}\right)^5\frac{\sin\theta}{\theta}$$

$$=\frac{1}{\theta^{11}}(-10395\theta^5\cos\theta+155925\theta^4\sin\theta+1091475\theta^3\cos\theta$$

$$-4365900\theta^2\sin\theta-9823275\theta\cos\theta+9823275\sin\theta) \quad \cdots\cdots(55)$$

The compressional phase velocity V_l is also defined as[5]

$$V_l^2=\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)} \quad \cdots\cdots(56)$$

Now, since

$$ha=\frac{\omega a}{V_l} \quad \text{and} \quad ka=\frac{\omega a}{V_s} \quad \cdots\cdots(57)$$

Then since Lame's constants[11]

$$\mu=G \quad \text{and} \quad \lambda^2=\frac{h^2}{k_2} \quad \cdots\cdots(58)$$

From equations (56), (57), (58) and (7), we have

$$\lambda^2=h^2/k^2$$

$$=V_s^2/V_l^2$$

$$=\frac{G/\rho}{E(1-\nu)/\rho(1+\nu)(1-2\nu)}$$

$$=\frac{0.5-\nu}{1-\nu} \quad \cdots\cdots(59)$$

where ω is the angular velocity of every particle in harmonic motion and ρ is the density of the sphere.

For the mixed mode of vibration, the stress free boundary condition on the spherical surface (r=a) requires that[11,12,16]

$$A_n\omega_n+C_n\phi_n=0 \quad \cdots\cdots(60)$$

and

$$B_n\omega_n+D_n\phi_n=0 \quad \cdots\cdots(61)$$

where ω_n stands for a spherical solid harmonic of positive degree n, and ϕ_n is a solid harmonic of positive degree n. The coefficients A_n, B_n, C_n and D_n are given as follows[11,12,16]:

$$A_n=\frac{1}{h^2}\left(\frac{k^2a^2}{2n+1}\Psi_n(ha)-2(n-1)\Psi_{n-1}(ha)\right) \quad \cdots\cdots(62)$$

$$B_n=-\frac{k^2a^{2n+3}}{h^2(2n+1)}\left(\Psi_n(ha)+\frac{2(n+2)ha}{k^2a^2}\Psi_n'(ha)\right) \quad \cdots\cdots(63)$$

$$C_n=-\left(\frac{k^2a^2}{2n+1}\Psi_n(ka)-2(n-1)\Psi_{n-1}(ka)\right) \quad \cdots\cdots(64)$$

$$D_n=-\frac{nk^2a^{2n+3}}{(n+1)(2n+1)}\left(\Psi_n(ka)+\frac{2(n+2)}{ka}\Psi_n'(ka)\right) \cdots\cdots(65)$$

2.3.1 Case n=2 ($\nu<0.5$)

Considering n=2, the equations (60) and (61) become

$$\left(\frac{k^2a^2}{5}\Psi_2(ha)-2\Psi_1(ha)\right)\frac{\omega_2}{h^2}-\left(\frac{k^2a^2}{5}\Psi_2(ka)-2\Psi_1(ka)\right)\Phi_2=0 \quad \cdots\cdots(66)$$

and

$$\left(\Psi_2(ha)+\frac{8ha}{k^2a^2}\ \Psi_2'(ka)\right)\frac{\omega_2}{h_2}+\frac{2}{3}\left(\Psi_2(ka)+\frac{8}{ka}\Psi_2'(ka)\right)\phi_2=0 \quad \cdots\cdots (67)$$

By eliminating the factor ω_2/ϕ_2 in equations (66) and (67) and expanding the results in rising power of H (=ka), the equation assumes the form

$$a_1-a_2H^2+a_3H^4-a_4H^6+a_5H^8-+\cdots=0 \quad \cdots\cdots (68)$$

The values of the coefficients are:

$$a_1=19-24\lambda^2 \quad \cdots\cdots (69)$$

$$a_2=\frac{37}{9}-\frac{7}{2}\lambda^2-\frac{4}{3}\lambda^4 \quad \cdots\cdots (70)$$

$$a_3=\frac{193}{792}+\frac{5}{126}\lambda^2-\frac{13}{56}\lambda^4-\frac{1}{33}\lambda^6 \quad \cdots\cdots (71)$$

$$a_4=\frac{25}{3861}+\frac{125}{11088}\lambda^2-\frac{1}{168}\lambda^4-\frac{185}{33264}\lambda^6-\frac{1}{2574}\lambda^8 \quad \cdots\cdots (72)$$

$$a_5=\frac{719}{7413120}+\frac{163}{432432}\lambda^2+\frac{19}{133056}\lambda^4-\frac{59}{299376}\lambda^6-\frac{253}{3459456}\lambda^8-\frac{1}{308880}\lambda^{10} \quad \cdots\cdots (73)$$

Substituting the relation between λ and ν from equation (59) for the case of $\nu=0.3$, equation (68) becomes

$$12.143-3.002H^2+0.235H^4-0.009H^6+0.0002H^8-+\cdots=0 \quad \cdots\cdots (74)$$

The first root of the frequency equation is H=2.6462, which corresponds to the simplest mode of this class, S_{20}. It is usually called oblate-prolate mode since the sphere is distorted into an ellipsoid and alternately becomes prolate and oblate according to the phase of the motion. Different ν value results in slightly different dimensionless frequency values.

2.3.3 Case n=3 ($\nu<0.5$)

Considering n=3, equations (60) and (61) become

$$\left(\frac{k^2a^2}{7}\Psi_3(ha)-4\Psi_2(ha)\right)\frac{\omega_3}{h^2}-\left(\frac{k^2a^2}{7}\Psi_3\ (ka)-4\Psi_2(ka)\right)\phi_3=0 \quad \cdots\cdots (75)$$

$$\left(\Psi_3(ka)+\frac{10ha}{k^2a^2}\Psi_3'\cdot(ha)\right)\frac{\omega_3}{h^2}+\frac{3}{4}\left(\Psi_3(ka)+\frac{10}{ka}\Psi_3'(ka)\right)\phi_3=0 \quad \cdots\cdots (76)$$

Eliminating ω_3/ϕ_3 in equations (75) and (76), and substituting the function values of Ψ_2, Ψ_3 and Ψ_3', one will get a complicated expressions of sine and cosine functions. The numerical solutions of the various roots for $\nu=0.1$, 0.2, 0.3 and 0.4, given by Cooke and Rand, are listed in Table 1.

2.3.3 Case n=4 ($\nu<0.5$)

Considering n=4, equations (60) and (61) become

$$\left(\frac{k^2a^2}{9}\Psi_4(ha)-6\Psi_3\ (ha)\right)\frac{\omega_4}{h^2}-\left(\frac{k^2a^2}{9}\Psi_4\ (ka)-6\Psi_3\ (ka)\right)\phi_4=0 \quad \cdots\cdots (77)$$

$$\left(\Psi_4(ha)+\frac{12ha}{k^2a^2}\Psi_4'(ha)\right)\frac{\omega_4}{h^2}+\frac{4}{5}\left(\Psi_4(ka)+\frac{12}{ka}\Psi_4'(ka)\right)\phi_4=0 \quad \cdots\cdots (78)$$

Elimination of ω_4/ϕ_4 in equations (77) and (78) and substitution of the function values of Ψ_3, Ψ_4, and Ψ_4', results in a complicated expressions of sine and cosine functions.

The numerical solutions of the various roots for the different Poisson's rations, $\nu=0.1$, 0.2, 0.3 and 0.4, given by Cooke and Rand, are also listed in Table 1.

Table 1. Mixed class non-dimensional free vibration frequencies of a homogeneous elastic sphere, $H_{n\ell-1}$

$\ell=$	$\nu=$	n=2	n=3	n=4
		H_{20}	H_{30}	H_{40}
1	0.1	2.6152	3.8360	4.8747
	0.2	2.6327	3.8927	4.9689
	0.3	2.6462	3.9374	5.0460
	0.4	2.6569	3.9731	5.1092
		H_{21}	H_{31}	H_{41}
2	0.1	4.4129	5.9597	7.5475
	0.2	4.7171	6.2920	7.8959
	0.3	5.0070	6.6086	8.2147
	0.4	5.2619	6.8811	8.4745
		H_{22}	H_{32}	H_{42}
3	0.1	7.6340	9.1069	10.4555
	0.2	8.0884	9.5024	10.8375
	0.3	8.5272	9.8824	11.2250
	0.4	8.7591	10.1362	11.5163
		H_{23}	H_{33}	H_{43}
4	0.1	9.1699	10.8406	12.4908
	0.2	9.4539	11.3017	13.0631
	0.3	10.3759	12.4277	14.1626
	0.4	12.0138	13.4255	14.8026

RESULTS AND DISCUSSION

The Navier equation can be applied to simulate the vibration of a homogeneous elastic sphere. By using the scalar and vector potential to represent the displacement vector, one can obtain three equations, namely, the Legendre equation, the Bessel's equation and the trigonometric equation. The analytical soltuions to the Legendre equation are called the associated Legendre polynomials of the first kind, which governs the mode shapes of the vibration. The analytical solutions to the Bessel equation are the spherical Bessel functions of the first kind, which can be applied to solve the non-dimensional frequencies of either pure compressional modes, pure shear modes or mixed modes either analytically or numerically. The solutions to the trigonometric equation are the combination of sinusoidal and cosinusoidal functions.

The product of the trigonometric functions and the associated Legendre polyomials, $\sin(m\delta)\, P_n^{|m|}(\cos\theta)$ and $\cos(m\delta)\, P_n^{|m|}(\cos\theta)$, are known as tesseral harmonics of nth degree and $|m|$th order[17]. They are periodic functions on the surface of a unit sphere and the indices $|m|$ and n determine the number of nodal lines. For instance, m=0, the field is independent of the equatorial angle δ. If n is also zero, the function value is constant on the surface of the sphere. When n=1, the only nodal line is at the equator $\theta=90°$along which the function is zero. When n=2, there are two nodal lines parallel to the equator at $\theta=54.7°$and

$\theta=125.3°°$, and the sphere is divided into three zones[7,17]. The function is negative over the equatorial zone and positive over the polar zones. It is clear that there are n nodal lines that divide the sphere into n+1 zones within which the function value is alternately positive and negative. If $m\neq0$, the number of nodal lines parallel to the equator is $n-|m|$ and the function is zero at the poles due to the factor $\sin^{|m|}\theta$ in the associated Legendre equation.

The vibration modes of the first three resonant frequencies of an intact apple induced by striking the equator of the fruit were proved to be an S_{20}, S_{30}, and S_{40}, respectively[7,8]. If we assume that apples are elastic sphere with Poisson's ratio, $\nu=0.3$[3], from Table 1, the non-dimensional frequencies associated with these three modes are 2.6462, 3.9374 and 5.0460, respectively. These values can be applied to conjecture the second and the third resonant frequencies from the first resonant frequencies by the ratios of the non-dimensional frequencies. If one uses the first resonant frequencies to calculate the corresponding second and third resonant frequencies, the coefficient of determination (R^2) between the measured and the calculated second resonant frequencies was 0.978 for the Red Delicious apples and 0.967 for the Golden Delicious apples, while R^2 between the measured and the calculated third resonant frequencies was 0.964 for the Red Delicious apples and 0.960 for the Golden Delicious apples[7]. Furthermore, the slope of every regression line between the measured and the calculated second or third resonant frequencies was statistically proven to be unity [7]. The comparison between these theoretical and experimental results will be extensively demonstrated in the next article.

ACKNOWLEDGEMENTS

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彈性球體振動之研究[1]

黃 禮 棟[2]　陳 必 超[3]

摘 要

在球體座標系中，利用常量及向量方程式代入之分離變數法於理論上分析彈性球體之振動可以得到三角幾何方程式、雷詹德方程式及白賽爾方程式等三種方程式。其中之第一類雷詹德聯合方程式主宰振動模式，而第一類球體座標白賽爾方程式則可導出該振動模式之無次元頻率。一個均質彈性球體最簡單之振動模式爲純壓縮模式及純剪切模式。本文中闡釋純壓縮模式及純剪切模式中在某些情況與條件下之無次元頻率之解析方法。雖然各種混合振動模式之無次元頻率之解答因爲過於複雜以致於無法使用理論分析而必須借重電子計算機以數值方法計算以求取近似值，但文中仍然列入了由藍姆（Lamb）於1882年所發表之解析方法以及庫克（Cooke）與藍德（Rand）二人利用電子計算機以數值分析法計算所得到溥松比（Poisson's ratio）之值分別爲0.1，0.2，0.3及0.4等條件下之無次元頻率的數值供值參考。

關鍵詞：振動模式、無次元頻率、彈性球體。

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Jour. Agric. Res. China (中華農業研究) 43(4)：453～466 (1994)

臺灣薊馬之種類(3)[1]

王　清　玲[2]

摘要：本文爲系列記述臺灣薊馬種類報告之一，包括薊馬科 (Thripidae) 薊馬亞科 (Thripinae) 之棍薊馬族 (Dendrothripini) 2屬6種與腹毛薊馬族 (Sericothripini) 2屬3種。每種之描述包括名稱、形態特徵、棲所植物、世界分布等，亦包括同屬中各種之檢索。

關鍵詞：薊馬、臺灣、種類描述。

薊馬科 FAMILY THRIPIDAE

薊馬亞科 Subfamily Thripinae

身體表面大多爲橫紋，完全無網紋，或是僅有少許部位形成微弱網紋或橫向之連結紋。觸角第3、4節有微毛，末節不成爲極尖細之針狀。前翅至少具有上脈。此爲薊馬科中主要的一亞科。

棍薊馬族 Tribe Dendrothripini

觸角除末端2節以外之各節均短圓。後胸腹部之內叉骨 (furca) 大而明顯，其兩端呈U型，向上延伸至中胸內叉骨附近。腹部各節背板中對毛 (median pair of setae) 之著生點相距很近，短於該毛本身長度。

棍薊馬屬 *Genus Dendrothrips* Uzel

Dendrothrips Uzel, 1895：159. 模式種：*Thrips ornata* Jabl., 1894.

頭寬扁，頭頂於兩複眼內側下陷。觸角8或9節，第3、4節有單一或叉狀感覺錐，第3～6節有微毛。前胸背板有橫紋，無長毛。前翅前緣端部向下彎曲與後緣會合，前緣毛僅著生於中央，基部與端部均無。腹部背板兩側有網紋。

本屬世界共40種以上。

臺灣僞棍薊馬屬各種檢索表

1. 觸角第3、4節具單一感覺錐；前翅深色，中央有一透明帶 ………………茶棍薊馬 *D. minowai*
－觸角第3、4節具叉狀感覺錐 ……………………………………………………………2
2. 前翅有4條褐色橫帶；腹部背板無斑點 …………………………斑翅棍薊馬 *D. maltimaculatus*
－前翅無明顯深色或透明帶；腹部第3～6背板有灰斑 ……………………………斑棍薊馬*D. guttatus*

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斑棍薊馬 *Dendrothrips guttatus* Wang（圖 1）

Dendrothrips guttatus Wang, 1993：254-256.

雌蟲製片後體長約0.9mm。頭胸黃褐色，腹部淡黃色，第 2 及 7 、 8 節背板兩側灰褐，第 3 ～ 6 背板兩側各有 3 對灰斑。觸角淡黃色，第 5 節端部與第 6 ～ 8 節褐色。前、中足灰褐，後足腿節褐色，僅基部較淡；脛節與跗節淡黃，脛節中央淡褐。前翅基部透明，餘灰色，中央與亞基部稍淡。主剛毛淡褐色。

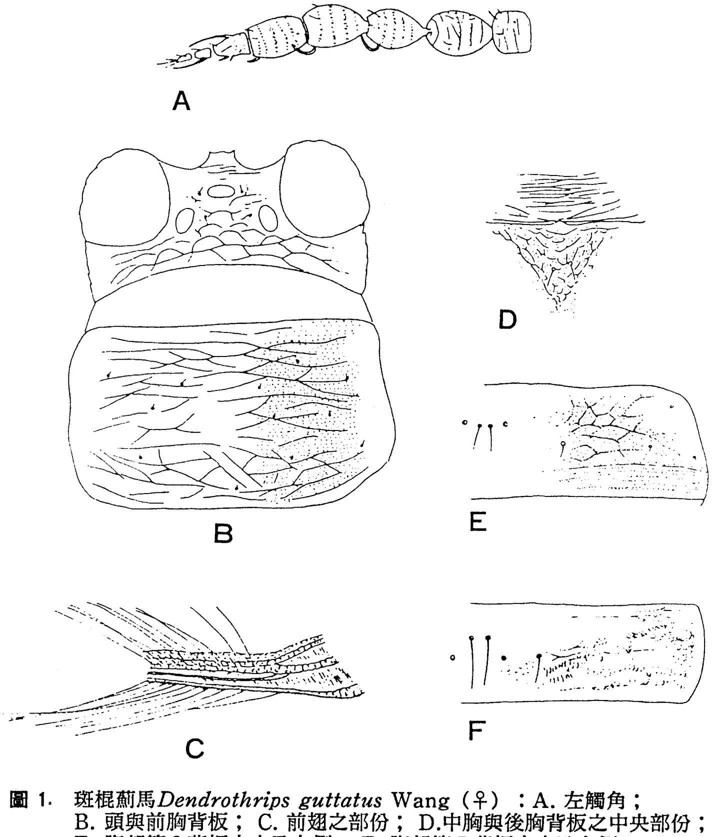

圖 1. 斑棍薊馬*Dendrothrips guttatus* Wang（♀）：A. 左觸角；B. 頭與前胸背板；C. 前翅之部份；D.中胸與後胸背板之中央部份；E. 腹部第 2 背板中央及右側；F. 腹部第 5 背板中央及右側。

Fig. 1. *Dendrothrips guttatus* Wang（♀）：A. left antenna ; B. head and pronotum ; C. portion of fore wing ; D. median portion of mesosternite and metasternite ; E. median and right portion of abdominal tergite II ; F. median and right portion of abdominal tergite V.

頭寬於長，背方有不規則網紋，內有小點。單眼毛短。小顎鬚 2 節。觸角 8 節，第 3 、 4 節有叉狀感覺錐，第 6 節內側有一感覺錐到達第 8 節基部。

前胸寬，背板有網紋，內有小點，無明顯長毛；中胸背板密生橫紋；後胸背板三角區有網紋，內有小點。前翅無微毛，脈毛極微小。

腹部第 2 ～ 8 背板中央平滑，兩測有網紋；第 2 、 3 、 7 、 8 背板之網紋明顯，內有小點；第 4 ～ 6 背板網紋不明顯，形成泡狀；第 2 ～ 8 背板中對毛愈向後愈長，第 6 背板中對毛極爲靠近；第 8

背板後緣中央有梳毛，兩側缺；第10背板中央不分裂。

雄蟲不詳。

分布：臺灣。

棲所植物：石栗（*Aleurites moluccana.*）。

標本檢查：♀（holotype），墾丁，13-I-1993。

斑翅棍薊馬 Dendrothrips maltimaculatus Nonaka & Okajima（圖 2）

Dendrothrips maltimaculatus Nonaka & Okajima, 1992：110-113.

雌蟲長1.1mm。頭、胸、足、第2腹節褐色，腹部第3、7～9節淡褐色，第4～6節黃色，背板各有2對褐斑。前翅透明無色，有4條褐色橫帶，以基部一條最寬。觸角第2、6～8節褐色，第1、5節淡褐，第3、4節黃褐。

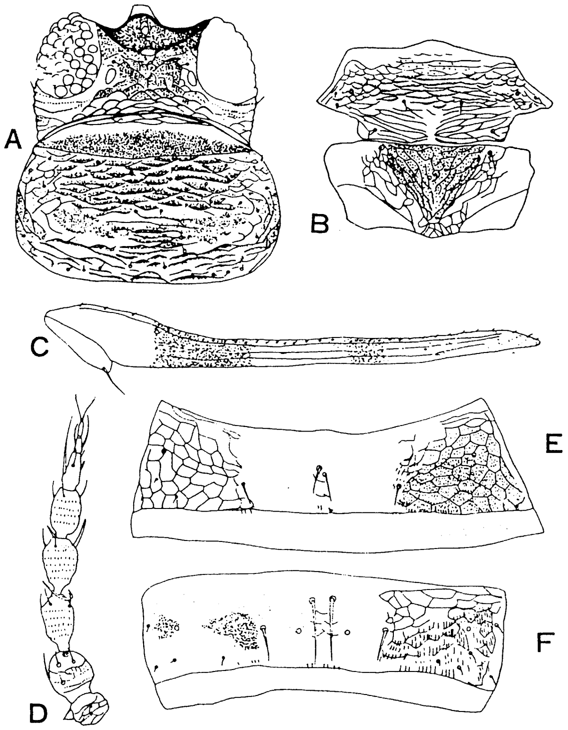

圖 2. 斑翅棍薊馬*Dendrothrips maltimaculatus* Nonaka & Okajima（♀）：
A. 頭與前胸背板；B. 中胸與後胸背板；C.前翅；D. 右觸角；E. 腹部第2背板；
F. 腹部第6背板。（Nonaka & Okajima 原圖）

Fig. 2. *Dendrothrips maltimaculatus* Nonaka & Okajima（♀）：A. head and pronotum；B. mesosternite and metasternite；C. fore wing；D. right antenna；E. abdominal tergite II；F. abdominal tergite VI.（after Nonaka & Okajima，1992）.

頭寬於長，背方有網紋，內有小點。單眼毛短小。觸角8節，第3、4節有叉狀感覺錐，第6節內側感覺錐伸達第8節末端。

前胸寬，背板不規則的網紋內有小點，無長毛，後緣毛6對，均短小；中胸背板有橫向之網紋，

內有小點，後胸背板直紋內有小點。前翅無微毛，上脈毛19～23支，下脈 2 ～ 4 支。

腹部第 1 背板平滑；第 2 背板兩側有明顯網紋，內有小點；第 3 ～ 6 節兩側網紋不明顯；第 7 節網紋明顯；第 8 背板後緣中央有梳毛，兩側缺；第10背板中央不分裂。

雄蟲體長0.8mm。似雌蟲但顏色稍淡，網紋較微弱；前翅有 3 條褐帶。

分布：臺灣、日本。

棲所植物：櫟（*Quercus* sp.）。

標本檢查： 1 ♀，南投，28-III-1984 (S. Okajima 標本)。

茶棍薊馬 *Dendrothrips minowai* Priesner（圖 3 ）

（三輪薊馬、山茶棘皮薊馬）

Dendrothrips minowai Priesner, 1935 : 353.

雌蟲製片後體長約1.0mm。體黃褐色或赤褐色，有紅色素，但腹部末端 3 節無紅色素，且顏色較淡。觸角第 1 節灰黃色，第 2 節深黃色，第 3 ～ 5 節淡黃色，但第 5 節端部較暗，第 6 ～ 8 節暗褐色。前翅深灰色，近中央有一無色透明帶。足黃褐色，前足顏色淡於中、後足。

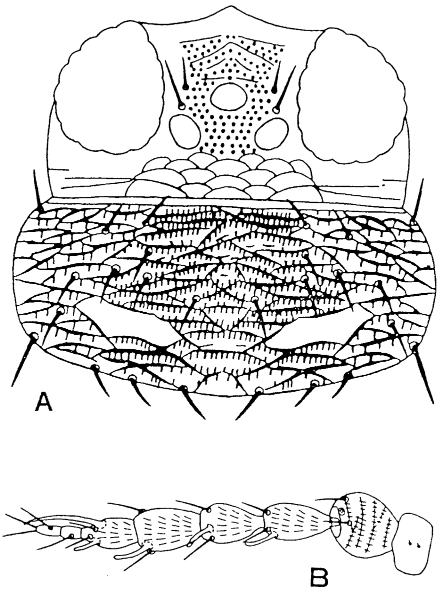

圖 3. 茶樹薊馬*Dendrothrips minowai* Priesner (♀) ：A. 頭與前胸；B. 左觸角。（陳連勝原圖）

Fig. 3. *Dendrothrips minowai* Priesner (♀) ：A. head and pronotum ; B. left antenna. (after Chen, 1979)

頭寬於長，背方紋路顯著。單眼間距寬，單眼間毛位於後單眼上方之單眼三角區之外，複眼後無剛毛。小顎鬚 2 節。觸角 8 節，第 3 、 4 節外側單一感覺錐短小，第 6 節內側有一感覺錐伸達或超過第 8 節末端。

前胸寬，背板有網紋，無明顯長毛，左右前緣角及後緣角各有 1 支短毛，後緣中央 3 對短毛。前翅翅毛微小，前緣毛約38支，上脈毛基部 6 ～ 7 支，端部 3 支。

腹部第1背板全部及第2～10背板兩側有網紋；第1背板中對毛微小而彼此間距大，第2～8背板中對毛著生點相近，第2～4節中對毛較短，長度未達該節背板之後緣，第5～8節者長度則超過背板後緣；第8背板後緣中央有梳毛，兩側缺。腹板無附毛。

雄蟲不詳。

分布：臺灣、中國大陸、日本。

棲所植物：茶（*Thea sinensis*），柿（*Diospyros kaki*）。

標本檢查：1♀，桃園楊梅，茶，XII-1976（陳連勝標本）。

僞棍薊馬屬 Genus *Pseudodendrothrips* Schmutz

Pseudodendrothrips Schmutz, 1913：992, 998. 模式種：*Pseudodendrothrips ornatissima* Schmutz, 1913.

頭寬扁。觸角8或9節，第3、4節有叉狀感覺錐。前胸背板有橫紋，後緣角各有1支長毛。前翅前緣端部不向下彎曲，前緣毛自基部至端部均有。腹部背板兩側有橫紋，其間有細小微毛。

本屬世界共8種。

臺灣僞棍薊馬屬各種檢索表

1. 前胸背板網紋間有細小直紋……………………………………………………觀音山薊馬*P. Fumosus*
—前胸背板網紋間無小紋……………………………………………………………………………………2
2. 體色灰白；觸角8節………………………………………………………………………桑薊馬*P. mori*
—體褐色；觸角9節………………………………………………………………側僞棍薊馬*P. lateralis*

觀音山薊馬 *Pseudodendrothrips fumosus* Chen（圖4）

（灰偽棍薊馬）

Pseudodendrothrips fumosus Chen, 1980：171，172.

雌蟲製片後體長 0.95 mm。體黃褐色，觸角第1、2節褐色，第3節黃褐色，第4～6節灰黃色且末端較深，第7～9節黃褐色。中胸背板後2／3灰黃色。腹部兩旁褐色，中央黃褐色，第3～8節近前緣有一條褐色節前脊。前翅灰色，基部與端部較淡。腿節褐色，脛節中央灰褐，兩端黃色，跗節黃色。

頭寬於長，背方中央有橫紋，其間再生細小紋路。單眼前毛2對，單眼間毛1對。口錐圓，抵達前胸後緣，小顎鬚2節。觸角9節，第1節方形，第2節最大且近乎球形，向端部各節漸細；第2節有明顯橫紋，第2～6節背方有微毛，第3、4節有叉狀感覺錐。

前胸寬於長，背板有橫紋及細小直紋，後緣角長毛2對，靠外側一對較長，中央有2對後緣毛。中胸背板佈有橫紋，中對毛之著生點靠近該節後緣。後胸腹面內叉骨特大。前翅前緣毛28支，上脈毛7支，粗大。後足跗節比前、中足跗節長，後脛節背方有1支長毛，後跗節有2支長毛。

腹部第1背板前半中央、第2～7背板兩旁、第8背板前半兩旁均有橫紋，其中第2～7背板之橫紋排列緊密，中間再生有細小直紋；第2～8背板中對毛位置靠近，愈向後方之數節此毛愈長；第2～7背板兩旁及後緣中央、第8背板兩旁及後緣全部、第9、10背板後半均有微毛；第10節完整不分裂。第2～6腹板全部及第7腹板兩旁有橫紋及微毛。（根據陳連勝1980原文描述）

雄蟲不詳。

分布：臺灣。

棲所植物：桑（*Morus* spp.）。
標本檢查：無。

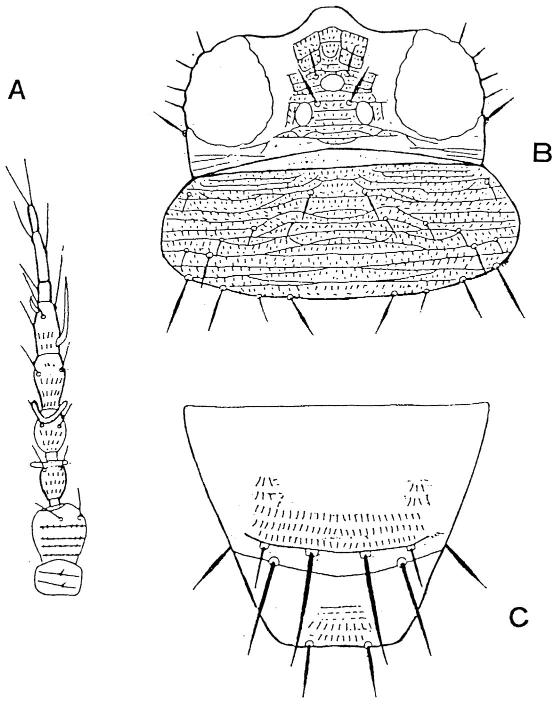

圖 4. 觀音山薊馬*Pseudodendrothrips fumosus* Chen（♀）：A. 左觸角；B. 頭與前胸背板；C. 腹部第 9 、10背板。（陳連勝原圖）

Fig. 4. *Pseudodendrothrips fumosus* Chen（♀）：A. left antenna；B. head and pronotum；C. abdominal tergites IX and X.（after Chen, 1980）

側僞棍薊馬 *Pseudodendrothrips lateralis* Wang（圖 5）

Pseudodendrothrips lateralis Wang, 1993：253-254.

雌蟲製片後體長0.7～0.95mm。頭胸桔褐色，腹部黃色，其中第 2 ～ 7 背板兩側2／3灰黑色，尤以第 2 ～ 7 節後緣較黑。觸角第 1 ～ 3 節黃褐，第 4 ～ 9 節灰褐色，其中第 4 ～ 6 節基部較淡。各腿節、脛節褐色，脛節基部及亞端部黃色，跗節黃色。前翅灰色，基部與端部較淡。

頭寬於長，單眼毛短小，單眼間毛 1 對，位在後單眼前半部之間。複眼之間生有橫紋。小顎鬚 2 節。觸角 9 節，形似前種，第 3 、 4 節有叉狀感覺錐，第 6 節基部內側與第 8 節基部外側各有一感覺錐甚長，後者超過第 9 節。

前胸寬，背板有橫紋，後緣角長毛 1 對，中央後緣毛 3 對。後脛節有一距，長於前、中脛節，跗節 2 節。前翅上脈毛 6 支，分開很遠，下脈無毛；前緣基部1/4及端部1/9無纓毛，前緣剛毛19～25支。

腹部第 2 ～ 8 背板兩側有成排微毛，尤以第 2 節與第 5 ～ 7 節較明顯；第 2 ～ 8 背板各中對毛位

置互相靠近，愈向後節愈長；第 2 ～ 7 節中央網紋微弱；第 8 節背板後緣梳毛完整；第10節完整不分裂。腹板無附毛。

雄蟲長0.67mm。頭、胸以及腹部第 1 、 2 節兩側桔褐色，腹部其餘部份爲黃白色，第 6 ～ 8 節兩側灰色。

分布：臺灣。

棲所植物：桑（*Morus* spp.），相思木（*Acacia confusa*）。

標本檢查：♀（holotype），臺中市，桑，1-III-1991；♂（allotype），墾丁，相思木，13-IV-1993。

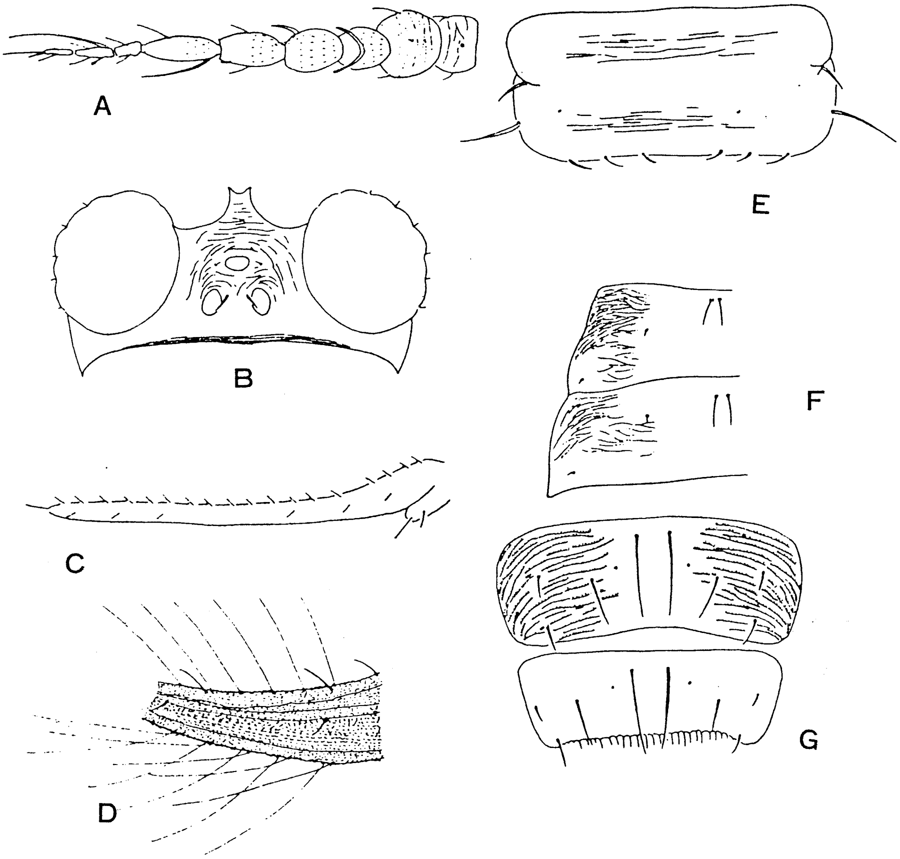

圖 5. 側僞棍薊馬*Pseudodendrothrips lateralis* Wang（♀）：
A. 右觸角；B. 頭；C. 前翅；D. 前翅部份之放大；E. 前胸背板；
F. 腹部第 2 、 3 背板之中央及左半部；G. 腹部第 7 、 8 背板。

Fig. 5. *Pseudodendrothrips lateralis* Wang（♀）：A. right antenna ; B. head ; C. fore wing ; D. portion of fore wing ; E. pronotum ; F. median and left portion of abdominal tergites II, III ; G. tergites VII, VIII.

桑薊馬 *Pseudodendrothrips mori* (Niwa)（圖 6）

Belothrips mori Niwa, 1908：180.

雌蟲製片後體長1mm。體色極淡，幾乎無色。觸角第 1 節顏色最淡，與體色相同，第 2 節淡褐，向

後各節顏色愈深。單眼有紅色素。前翅淡黃或灰黃色。

頭寬於長，複眼之間生有微弱網紋。小顎鬚 2 節。觸角 8 節，形似前種，第 3 、 4 節橢圓形，各有 1 叉狀感覺錐，第 7 節細長，有時有淡的橫斜縫（使外觀看似共有 9 節），第 8 節細長，長度約爲第 7 節的一半。

前胸寬，背板布滿細橫紋，但中央兩側各有一個光滑無紋區，後緣角各有 1 對長毛，後緣中央有 2 對略短毛。中胸腹部內叉骨無刺，後胸腹部內叉骨大。前翅前緣毛約24支，上脈基部有 3 支，中部 1 支，端部 2 支。足細長，跗節 1 節，後跗節較長。

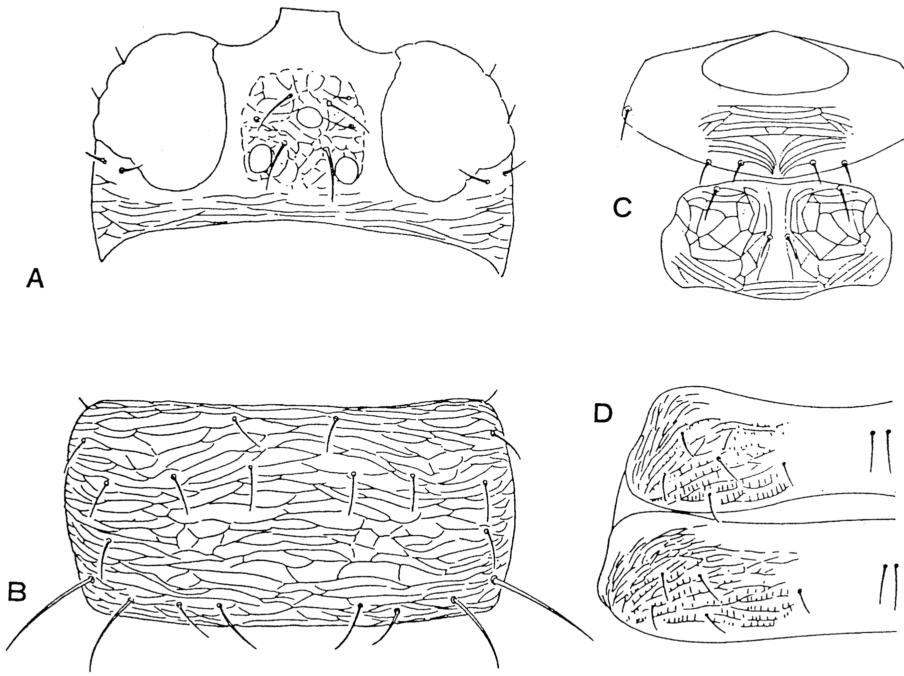

圖 6. 桑薊馬*Pseudodendrothrips mori*（Niwa）（♀）：
A. 頭；B. 前胸背板；C. 中胸與後胸背板（陳連勝原圖）；
D. 腹部第 2 、 3 背板之中央及左半部。

Fig. 6. *Pseudodendrothrips Nori* (Niwa) (♀) ; A. head ; B. pronotum ; C. mesosternite and metasternite (after chen, 1980) ; D. median and left portion of abdominal tergites II and III.

腹部第 2 ～ 9 背板兩側及第10背板後半部有成排微毛；第 2 ～ 8 背板各中對毛位置相靠近，愈向後節愈長；第 8 背板後緣梳毛完整；第10節完整不分裂。腹板無附毛。

雄蟲一般構造和體色與雌蟲相似。腹部第 9 背板兩側無粗剛毛；腹板無腺室。

分布：臺灣、中國大陸、日本、美國。

棲所植物：桑樹（*Morus* spp.)。

標本檢查： 1 ♀，臺中霧峰。

附記：本種在桑樹上普遍存在，曾經爲桑樹害蟲。目前蠶桑業逐漸沒落，桑樹栽植面積漸減少，本種薊馬亦失去經濟重要性。

腹毛薊馬族 Tribe Sericothripini

頭背與頸區分明顯。前胸背板有板塊（blotch）；中胸有內叉骨刺，後胸無。前翅有微毛，上脈毛排列均勻完整，下脈毛 0～2 支。腹部各節之背板均生有濃密微毛，第 2～7 背板前緣脊之兩側有向前之突出點。有些種類腹板亦有微毛。

板背薊馬屬 Genus *Hydatothrips* Karny

Hydatothrips Karny, 1913 : 281. 模式種：*Hydatothrips adolfifriderici* Karny, 1913.

頭寬於長。觸角 8 節，第 3 、 4 節有叉狀感覺錐。前胸背板有一邊緣明顯之板塊；後胸腹板中央有一 Y 型骨將腹板分成左右兩塊。第 1～7 背板兩側密生微毛；第 2～6 背板後緣有梳毛，兩旁長，中央短小或缺；第 8 背板後緣梳毛完整。第 2～4 背板中對毛間距離較近，毛較短；第 5～7 節中對毛距離較遠，毛較長。

本屬世界共13種。

田菁板背薊馬 *Hydatothrips ekasi* Kudo（圖 7）

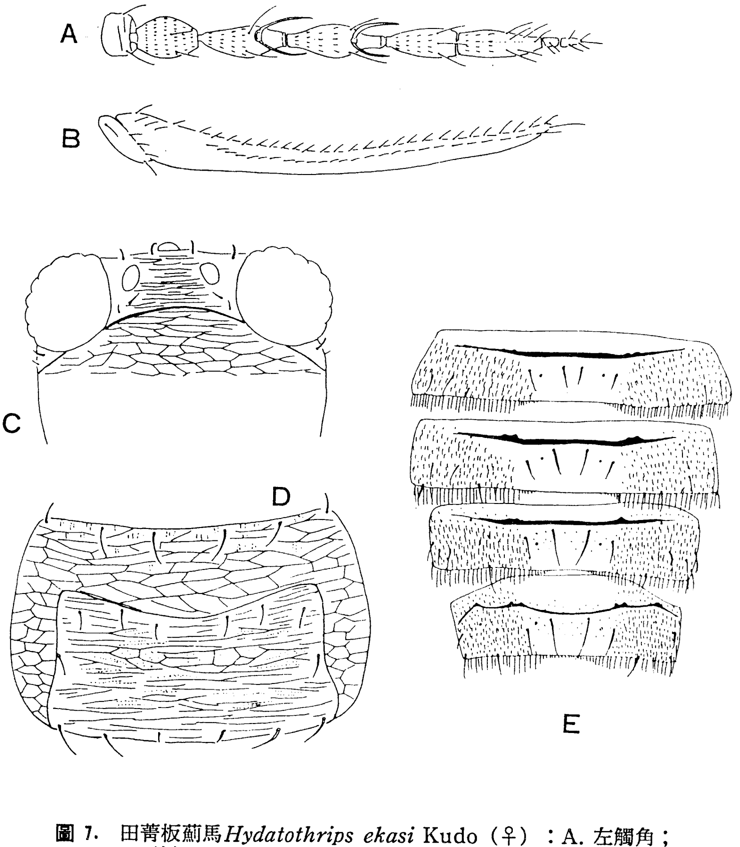

圖 7. 田菁板薊馬*Hydatothrips ekasi* Kudo (♀) ：A. 左觸角；B. 前翅；C. 頭；D. 前胸背板；E. 腹部第 4～7 背板。

Fig. 7. *Hydatothrips ekasi* Kudo (♀) ：A. left antenna ; B. fore wing ; C. head ; D. pronotum ; E. abdominal tergites IV-VII.

Hydatothrips ekasi Kudo, 1991：520-523.

雌蟲製片後體長1.2～1.3mm。頭、胸深褐色，腹部第1～3節及第6、10節褐色，第4、5節黃色，第7～9節深褐色，第2～7節前緣脊黑褐色。觸角第1～3節黃色，但第3節端部稍褐，第4節基部1/4黃色餘褐色，第5～8節褐色。前翅亞基部有一透明區，餘褐色。前腿節淡褐色，中、後腿節稍深褐色，各脛節與跗節黃色。

頭甚扁，背方有細橫紋。頸區大，長度爲頭長3倍以上，頸區內前半部有網紋，後半部無紋。單眼間毛位在後單眼前方之內側。口針窄長，達中胸前緣；小顎鬚3節，細長。觸角8節，第3、4節有叉狀感覺錐。

前胸背板板塊以外之區域有網紋，網紋內有不顯著之小點；板塊上有細橫紋，前緣4對毛，側方1對毛，後緣3對毛。中後胸背板網紋內有小點刻形成之紋路。前翅上脈毛完整，下脈無毛。跗節2節。

腹部第1～7背板兩側有密生之微毛；第1～6背板後緣兩側有梳毛，中央缺；第1～4節之中對毛相靠近，第5～8節中對毛距離較遠，毛較長；第2～7背板前緣脊之亞側方向前突出，尤以第7節最爲明顯；第8背板後緣梳毛完整，約等長。腹板無附毛。

雄蟲形狀與雌蟲相似，顏色稍淡；腹部第1～7背板中央無梳毛；第5～7腹板有橫生之腺室。

分布：臺灣、日本。

棲所植物：雞眼草（*Kummerovia striata*），田菁（*Dioscorea benthamii*），血桐（*Macaranga tanarius*）。

標本檢查：3♀1♂（paratypes），Shizuoka，日本，12-VIII-1979，雞眼草（I. Kudo 標本）；5♀1♂，臺中霧峰。

楓樹板背薊馬 Hydatothrips liquidambara Chen（圖8）

Hydatothrips liquidamara Chen, 1977：145-147.

雌蟲製片後體長1.2-1.4mm。頭、胸褐色，腹部第1～4節及第6～9節灰褐色，第5節黃色且中央顏色較深，兩側稍淡，第10節淡黃色，第2～7節前緣脊黑褐色。觸角第1、2節黃色，第3節淡褐，第4節褐色但基部1／4黃色，第5～8節褐色。前翅亞基部有一透明區，餘褐色。前腿節黃色，邊緣褐色，中、後腿節深褐色，各脛節與跗節黃色。

頭甚扁，背方有細橫紋，頸區寬大，長於頭背，其內前方有細橫紋，繼之爲網紋，然後無紋。單眼前毛2對，單眼間毛1對，位於後單眼前方之內側。口針窄長，達前胸後緣；小顎鬚3節，細長。觸角8節，第3、4節有叉狀感覺錐。

前胸背板板塊以外之區域有較大網紋，內有多數小點；板塊上有細橫紋，前緣3對毛，側方2～3對毛，後緣2對毛；中、後胸背板網紋內均有小點刻形成之紋路。前翅上脈毛完整，下脈毛0～2支，左右翅之下脈毛數目可能不同，但至少其中一翅上會有至少一支剛毛。跗節2節。

腹部第1～7背板兩側有密生之微毛；第2～7節後緣梳毛兩旁較長，中央短小；第1～4節之中對毛互相靠近，第5～8節中對毛距離較遠，毛較長；第2～7背板前緣脊之亞側方向前突出，尤以第7節最爲明顯；第8背板後緣梳毛完整，約等長。腹板無附毛。

雄蟲與雌蟲相近，體長0.9-1.1mm。腹部第6～8腹板有橫生腺室。

分布：臺灣。

棲所植物：小葉桑（*Morus australis*），雜草。

標本檢查：1♀，梅峰，小葉桑，24-X-1978（陳連勝標本）。

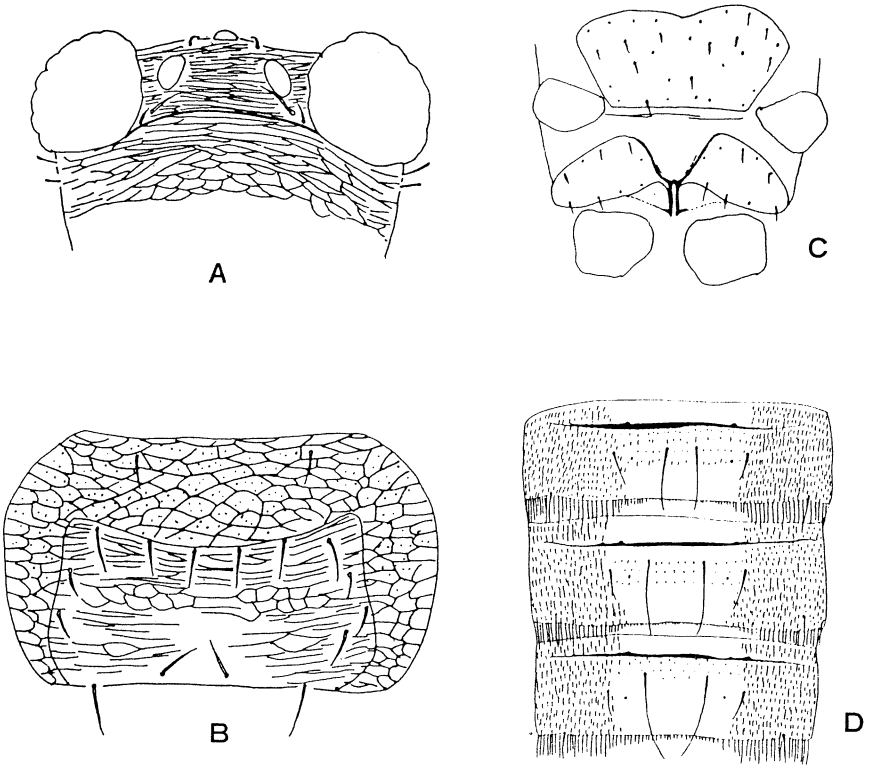

圖 8. 楓樹板背薊馬*Hydatothrips liquidambara* Chen（♂）：
A. 頭；B. 前胸背板；C. 中胸與後胸腹板；D.腹部第 4 ～ 6 背板。
Fig. 8. *Hydatothrips liquidambara* Chen（♂）：A. head；B. pronotum；C. mesosternum and metasternum；D. abdominal tergites IV-VI.

新板薊馬屬 Genus Neohydatothrips John

Neohydatothrips John, 1929：33. 模式種：*Nohydatothrips latereostriatus* John.

本屬與板背薊馬屬之差異在於其後胸腹板中央互相結合，並不分隔成爲左右兩塊。

本屬世界共16種。

中板背薊馬 Neohydatothrips medius Wang（圖 9）

Neohydatothrips medius Wang, 1994：257-259.

雌蟲製片後體長約1.2mm。頭胸深褐色，腹部第 1 ～ 4 節兩旁深褐；中央淡褐，第 5 、 6 節淡黃褐，第 7 ～10節深褐，各節前緣脊黑褐。觸角第 1 、 2 節淡黃，第 3 節淡褐，第 4 節淡黃；末端淡褐，第 5 節基部1/2淡黃；端部淡褐，第 6 ～ 8 節褐色。各足腿節深褐，脛節與跗節淡黃褐。前翅亞基部透明無色，餘褐色。

頭甚扁；頸區比頭長，其內前半部有細橫紋，後半部無紋，但有許多小黑點；頭與頸區網紋內有小紋。單眼間毛在後單眼前。口錐到達中胸前緣，小顎鬚 3 節。觸角 8 節，第 3 、 4 節有叉狀感覺錐

，第 6 、 7 節有線形感覺區，第 2 ～ 6 節有微毛。

前胸背板板塊以外之區域有細小橫紋，紋內再有小紋；長方形板塊上有極細小橫紋，前方與兩旁前緣有毛 4 對，後緣角各有一支長毛，後緣毛 1 對。中後胸背板密佈橫紋，內有小紋。前翅上脈毛 3 ＋18支，下脈端毛 2 支。

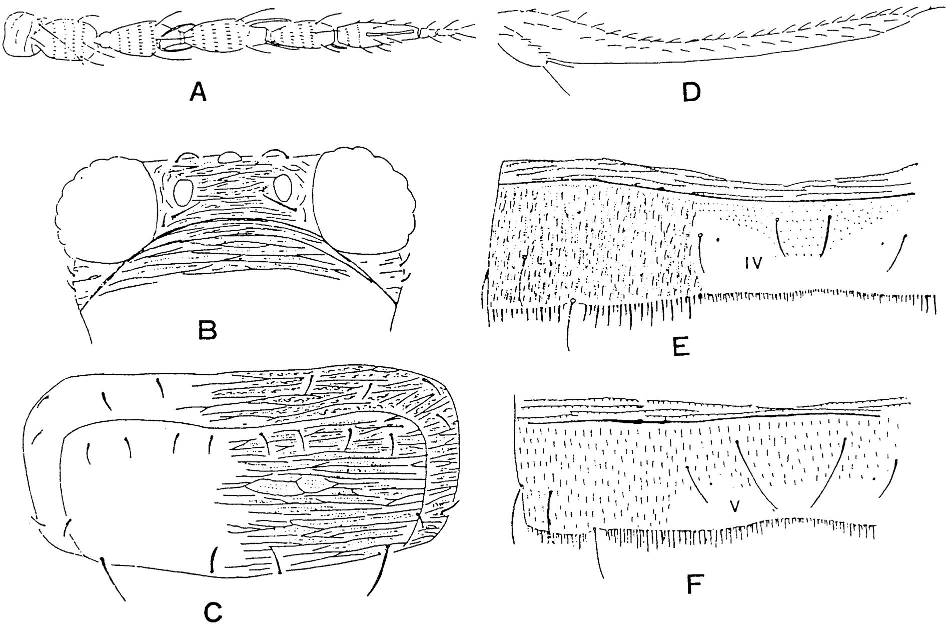

圖 9. 中板背薊馬*Neohydatothrips medius* Wang（♀）：A. 右觸角；B. 頭；C. 前胸背板；D.前翅；E. 腹部第 4 背板；F. 腹部第 5 背板。

Fig. 9. *Neohydatothrips medius* Wang（♀）：A. right antenna；B. head；C. pronotum；D. fore wing；E. abdominal tergite IV；F. abdominal tergite V.

腹部第 1 背板兩側有密生之微毛及後緣梳毛；第 2 ～ 4 背板兩側微毛較粗且有小紋於其間；第 5 ～ 8 背板有微毛，但第 5 、 6 節中央無。第 2 ～ 7 背板後緣梳毛生於兩側者較長，中央極短小；第 8 背板後緣梳毛完整，約等長。第 1 ～ 4 背板中對毛互相靠近，第 5 ～ 8 背板中對毛分開較遠。

雄蟲製片後長約0.8mm。外形顏色與雌蟲相似，腹部無腺室；第 9 背板有長毛 4 對；第10背板有微毛。

分布：臺灣。

棲所植物：雜草、樟木（*Cannamomun camphora*）。

標本檢查： 1 ♀（holotype）& 12♀ 2 ♂（paratypes），屏東，樟木，21-IV-1992。

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Thysanoptera of Taiwan (3)[1]

Chin-Ling Wang[2]

Summary

This is one of the series papers to describe the thrips of Taiwan. Two genera and six species of tribe Dendrothripini and two genera and three species of tribe sericothripini are described, which contains morphological characteristics, plants where it collected and world distribution.

Key words : Thysanoptera, Taiwan, Review.

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Jour. Agric. Res. China (中華農業研究) 43(4)：467～468 (1994)

臺灣新發現黔梨木蝨（同翅目：木蝨科）[1]

周樑鎰　方尚仁[2]

摘要：本文首次記錄危害臺灣梨樹之黔梨木蝨（*Psylla qianli* Li & Yang），而且該木蝨亦爲臺灣之新記錄種。

關鍵詞：黔梨木蝨、木蝨科、梨樹。

民國83年6月於臺中縣東勢、和平地區之梨樹發現疑似由「類菌質」所引起之梨衰弱病（Pear decline），罹病株樹勢衰弱，果實發育不良，葉片變小而少，並由葉緣開始轉紅而擴及全葉，鬚根腐爛。罹病區域呈點狀或帶狀分布。如果該病確係由「類菌質」所引起之梨衰弱病，則據國外報告其可經由接穗及木蝨媒介傳播[3,4]。但因未嫁接之鳥梨發病亦相當嚴重，顯示應有自然傳播之情形；但臺灣以往並無梨木蝨之記錄。故筆者等乃探討臺灣是否有梨木蝨存在。

梨衰弱病最早於1948年在英屬哥倫比亞之西洋梨（*Pyrus communis* L.）上發現，且曾在北美、捷克、法國、希臘、意大利、瑞士、德國及南斯拉夫等國摧毀大量之栽培梨樹；該病可經由梨黃木蝨（*Psylla pyricola* Foerster）媒介傳播[3,4]。因而梨黃木蝨爲歐洲與北美重要之梨樹害蟲；此外歐洲尙有西洋梨木蝨（*P. pyrisuga* Foerster）與梨木蝨（*P. pyri* （Linnaeus））兩種木蝨[2]。

木蝨屬（*Psylla*）之一些種類亦爲中國大陸北方重要梨樹害蟲，成蟲與若蟲均刺吸梨樹的芽、葉及嫩梢，除直接消耗營養外，受害葉出現褐色枯斑，甚至全葉變黑；嚴重的梨園葉片被害高達90%以上，造成早期落葉，不能按時開花；新梢受害後，有萎縮現象而發育不良。此外，梨木蝨經常排出大量蜜露，招致黑霉衍生、污染果實，影響光合作用，使樹勢衰弱，降低產量與品質[2]。

在中國大陸已知可危害梨屬果樹之木蝨有如下之18種：艾梨木蝨（*P. aili* Li & Yang）；杜梨木蝨（*P. betulaefoliae* Yang & Li）；蒼山梨木蝨（*P. cangshanli* Li & Yang）；昌梨木蝨（*P. changli* Yang & Li）；中國梨木蝨（*P. chinensis* Yang & Li）；滇梨木蝨（*P. dianli* Li & Yang）；洱海梨木蝨（*P. erhaili* Li & Yang）；異杜梨木蝨（*P. heterobetulaefoliae* Yang & Li；疆梨木蝨（*P. jiangli* Yang & Li）；昆明梨木蝨（*P. kunmingli* Li & Yang）；遼梨木蝨（*P. liaoli* Yang & Li）；褐梨木蝨（*P. phaeocarpae* Yang & Li）；梨木蝨（*P. pyri*(Linnaeus)）；黔梨木蝨（*P. qianli* Li & Yang）；思茅梨木蝨（*P. simaoli* Li & Yang）；黃梨木蝨（*P. xanthisma* Li & Yang）；下關梨木蝨（*P. xiaguanli* Li & Yang）；雲梨木蝨（*P. yunli* Li & Yang）[1,2]。

筆者等於民國83年10月21日在南投縣梅峰首先採得危害梨樹（*Pyrus pyrifolia* Nakai）之木蝨，經攜回實驗室鑑定，結果爲原分布於中國大陸貴州省之黔梨木蝨。一周後（10月28日）於臺中縣東勢通往鞍馬山公路之13公里處，亦即梨衰弱病發生嚴重地區又採得該木蝨；該木蝨產卵於梨樹之花芽

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、嫩葉及嫩梢上。其後復於11月11日在臺中縣佳陽（靠近梨山）採得該木蝨之卵。目前雖尚未能證明黔梨木蝨是否可以傳播東勢地區之梨衰弱病，但因木蝨之發現，可提供進一步研究之材料。

誌 謝

本研究承農業試驗所陳文華、陳健忠及翁振宇等先生協助部分調查，行政院農業委員會資助部分經費（84科技-1.3-糧-15(1)），謹此致誠摯謝意。

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New Record of *Psylla qianli* (Homoptera : Psyllidae) from Taiwan[1]

Liang-yih Chou and Shang-jen Fang[2]

Summary

Psylla qianli Li & Yang (Homoptera : Psyllidae) was recorded in Taiwan for the first time. This species is a pest of pear trees.

Key words : *Psylla qianli,* Psyllidae, Pear tree.

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A New Species of *Encarsiella* (Hymenoptera : Aphelinidae) from Taiwan[1]

Ken-Ching Chou and Liang-Yih Chou[2]

Abstract : *Encarsiella taiwanensis* sp. nov. (Hymenoptera : Aphelinidae) from Taiwan is described and illustrated.

Key words : Aphelinidae, Hymenoptera, Aleyrodidae, *Encarsiella,* Taiwan.

INTRODUCTION

The genus *Encarsiella* Hayat is a small group of the family Aphelinidae, being represented by 6 species in the world. Their hosts are Aleyrodidae and Plataspidae. This genus have been revised and keyed recently(2) ; it is recorded from Taiwan for the first time, and a new species is described in this paper. The terminology used in this paper follows Hayat (1). The specimens (including types) are deposited in the insect collection of the Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

Encarsiella taiwanensis sp. n.
(Figs. 1-5)

Female : Eye with very fine setae. Mandible with two teeth and a truncation. Antennal formula 1,1,3,3 ; flagellum slender and elongate. F1 and F2 subequal in length, each about 1.8 times width ; and about 1.4 times as long as pedicel. F3 about 1.5 times as long as wide, and 0.84 times as long as F1. Funicle about 1.4 times clava. F5 slightly oblique apically, F6 with sensorial complex. Flagellum with following numbers of longitudinal sensilla : F1:1; F2:2; F3:2; F4:3; F5:3; F6:2. Mid-lobe of mesoscutum with 41-50 setae, lateral lobe with 3 setae. Forewing : 2.3 times as long as wide ; submarginal vein with 2 large setae ; basal cell with 21-26 setae ; wing width about 10 times longest seta on marginal fringe. Hindwing : 5.0 times as long as wide ; marginal fringe 0.58 times as long as wing width. Tergum VII about 2.1 times as wide as long. Second valvifer about 2.0 times as long as third valvula. Ovipositor 0.57 times as long as mid tibia. Terga II-VII with 3-5 + 3-5, 4-5 + 4-5, 5+5, 5-6 + 2 + 5-6, 2-4 + 2-4 and 6 setae respectively.

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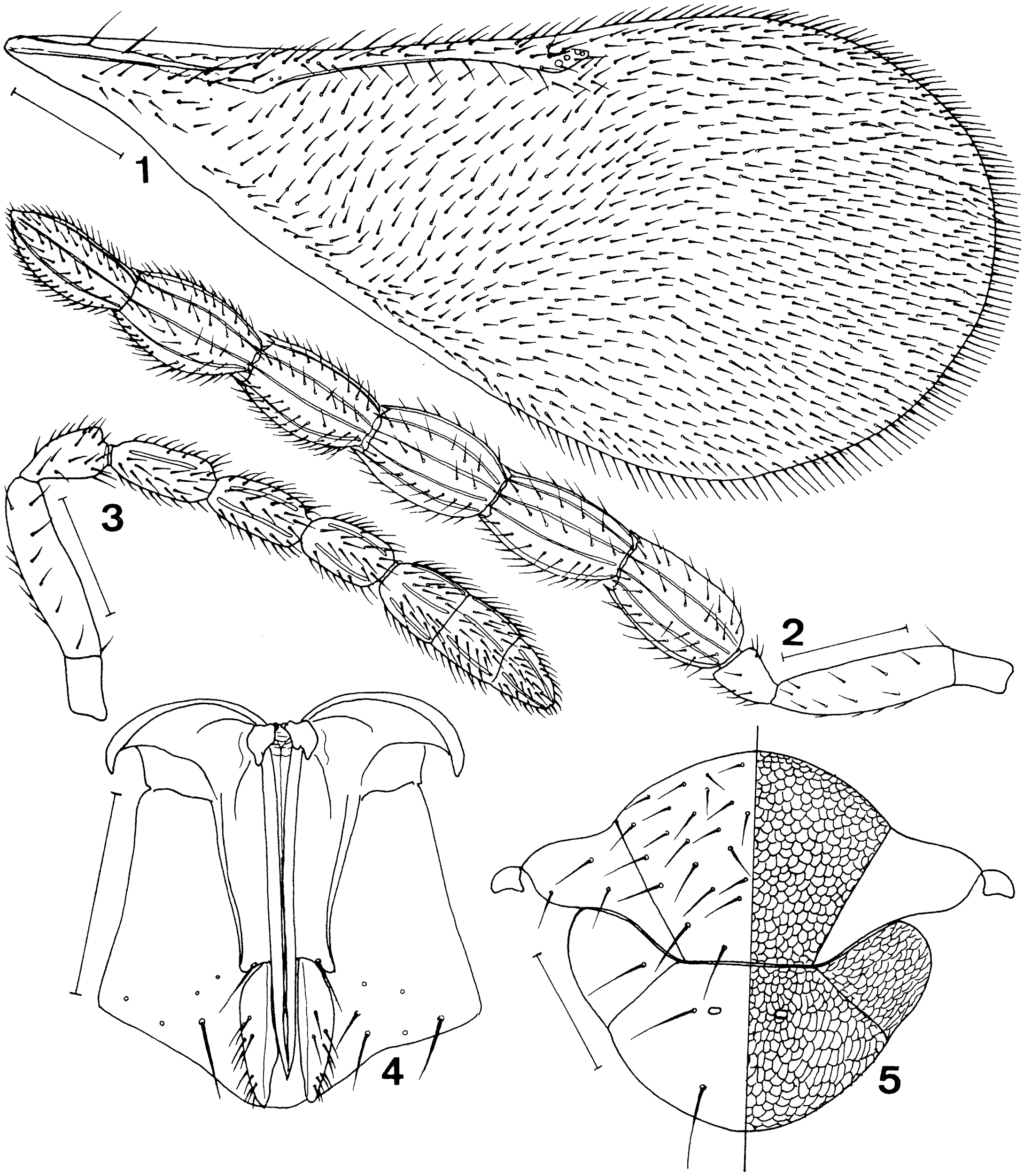

Figs. 1–5. *Encarsiella taiwanensis* sp. nov. 1, forewing, ♀ ; 2, antenna, ♂ ; 3, antenna, ♀ ; 4, ovipositor ; 5, mesonotum. ♀ (Scale 0.1mm).

Dark brown ; vertex orange red, frons brownish yellow. Antenna brownish yellow ; scape lighter, F1 brown, F4 and F5 dark brown. Wings hyaline. Legs pale yellow, mesocoxa, metacoxa, and most of metafemur brown.

Male : Similar to female. Pedicel almost as long as wide. All flagellar segments subequal in length, about 2.8 times as long as pedicel. Flagellum with following numbers of longitudinal sensilla : F1:7; F2:7; F3:9; F4:7; F5:7; F6:5. Vertex largely dark brown. Antenna brown, scape faintly brownish yellow, F2-F4 light brown.

Specimens examined : Holotype ♀, PINGTUNG, Kenting, 14.IX.1994 (K.C. Chou). Paratypes : NANTOU, Wushe, 1♀, 18.III.1994 (K.C. Chou). PINGTUNG, Henchun, 2♀2♂, 3.III.1994 (K.C. Chou) ; Kenting, 1♂, 21.IV.1994 ; 1♀2♂, 14.IX.1994 (K.C. Chou). TAIPEI, Yangmingshan, 2♀2♂, 27.I.1994 (K.C. Chou). All reared from *Aleurodicus machili.*

Distribution : Taiwan.

Host : *Aleurodicus machili* Takahashi (Aleyrodidae).

Remarks : Runs in the key to species of *Encarsiella* by Polaszek & Hayat[2] to *E. aleurodici* (Girault) which distributed in Barbados, Ecuador and Trinidad.. This species, however, can be easily discriminated from *E. aleurodici* by the pedicel of male almost as long as wide.

Etymology : Named after Taiwan.

ACKNOWLEDGEMENTS

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臺灣擬恩蚜小蜂屬(膜翅目：蚜小蜂科)一新種[1]

周根清　　周樑鎰[2]

摘　要

擬恩蚜小蜂屬（*Encarsiella*）隸膜翅目蚜小蜂科，目前全世界已知之種類約有 6 種；該屬首次記錄分佈於臺灣。本文描述 *Encarsiella taiwanensis* sp. nov. 之形態特徵，並輔以性狀圖說明。

關鍵詞：蚜小蜂科、膜翅目、粉蝨科、擬恩蚜小蜂屬、臺灣。

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中華農業研究稿約

一、本刊爲臺灣省農業試驗所發行之學術性季刊，刊登農業試驗研究相關之研究報告及研究簡報。

二、來稿可用中文或英文撰寫，包括原稿一份及影本二份（內各附照片原圖）。稿件以未在其他刊物發表者爲限。稿紙以 A4紙張（長29.6公分，寬21公分）打字列印，每頁以不超過二十五行爲原則，上下應預留3公分，左右2公分空間，以便審查。

三、來稿經編審委員會審查合格後刊登，由本刊印贈抽印本50本；彩色頁印刷及抽印本加印份數，由投稿人員負擔印製費用。

四、稿件格式請依以下說明繕打：

(一)第一頁爲中文稿之中英文題目、作者之中英文姓名；英文稿之英中文題目、作者之英中文姓名。英文題目除介系詞、連接詞等字外，每字第一字母應大寫；英文姓名：名字在前，姓氏在後，作者二人或二人以上，最後一人前加〝and〞字樣，其表示方法如 Chen-Seng Huang, Chen-Chang Chen and Chyr-Guan Chern。

(二)第二頁爲中（英）文稿之中（英）文摘要與關鍵詞。中、英文摘要均不分段落。中文摘要以不超過五百字，英文摘要（Summary）以不超過三百字爲原則。關鍵詞（Key words）不能超過五個，每個英文關鍵詞第一字母應大寫，其表示方法如 Key words：Heritability, Indirect selection.

(三)第三頁爲中(英)文稿之英(中)文摘要與關鍵詞。中、英文摘要與關鍵詞書寫方式比照上項辦理。

(四)第四頁爲臺灣省農業試驗所研究報告刊登之編號（編號謄空）、作者之註脚，如通信作者、發表場合、服務機關、及其他相關事項等，以小號數字表示順序。

(五)第五頁起爲本文，依序爲前言（INTRODUCTION）、材料與方法（MATERIALS AND METHODS）、結果（RESULTS）、討論（DISCUSSION）、誌謝（ACKNOWLEDGEMENTS，含計畫編號）、引用文獻（REFERENCES）、表、圖之說明（LEGEND）及圖，其中結果及討論兩項可合併爲「結果與討論（RESULTS AND DISCUSSION）」；研究簡報則不分章節，內容簡短，以不超過四印刷頁爲度（約6,000字）。農推、農經研究報告參考本方法書寫。

(六)表格應注意事項：

1. 表格應分別繕製，上方須有標題，並加表1（Table 1.），表2（Table 2.）等冠號。
2. 中文稿之表格標題應中英文並列，冠號與表幅齊頭，表內項目及內容以英文書寫。英文標題及各欄英文細目，除第一字之第一字母大寫外，餘均小寫。
3. 表中加註，需以 z, y, x, ……等縮小小寫字母置於右上角，並於表下依該縮小小寫字母逐次敍述。
4. 表格僅列橫線，直線全免。
5. 每一表格應在文中標示清楚，以便對照。

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1. 插圖（需爲封閉方格，正方形或長方形）以黑色墨水分別繪製在繪圖紙或描繪紙（白色透明紙）上。如以電腦繪圖，請以鐳射印表機或同規格之印表機列印，力求清晰。
2. 圖中加註者，應於圖說明中註明。
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4. 圖片及照片下方應有標題及說明，並加圖 1（Fig. 1.），圖 2（Fig. 2.）等冠號；中文稿應中英文併寫，力求簡短。
5. 照片、圖片背面應註上冠號及作者姓名，以免排印錯誤。
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1. 中、日文文獻以作者姓氏筆劃爲序，英文文獻以姓氏之字母爲序。中日韓英文併陳時，中文在前，日、韓文居次，英文隨後，其中作者相同，以年代爲序；同一作者同一年代之不同文獻，則增列 a, b, c 等區分。作者二位時，中、日、韓文文獻以〝和〞連接，英文文獻以〝and〞連接；作者三位或以上時，中、日、韓文文獻於第一作者後加〝等〞，英文文獻加〝*et al.*〞。
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4. 排序後之引用文獻前加註1，2，3……等序號；本文內容註明引用文獻出處時，直接以[1]或[1,2,3]等小號字表示。
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(1)文獻出自學術性刊物

1. 陳隆澤、胡念才。1983。水稻品種（系）對稻熱病抵抗性反應之研究。中華農業研究 32：1—13。
2. Hsu, S. H., T. Y. Chung, T. C. Kuo and S. F. Wang. 1992. Studies on the micro-climate of greenhouse. I. Light environment of greenhouse(in Chinese). J. Agric. Assoc. China 157：34—43.
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1. 楊清白。1980。家畜飼料學。74—108頁。藝軒。臺北。
2. Sung, J. M. 1991. Nitrogen Metabolism of Rice. p.100. Chinese Agronomy Press, Taipei.

(3)文獻出自編輯性書籍

1. Lo, W. S. 1991.The effect of calcium on nitrogen metabolism pp. 100—110. in: Biology of Rice. (Sung, J. M. and D. J. Liu, eds.) Chinese Agronomy Press, Taipei.

(九)文字敍述之號次以下列爲序：

1. 中文用：一、 (一) 1. (1) ①
2. 英文用：I. i A. a.

(十)單位採用 SI units 爲準，不另加中文。統計分析顯著性應加註說明。

(十一)生物學名應於下方加底線，以便排斜體字。

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七、其他未盡事宜得隨時修正或補充。

中華農業研究

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